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THESIS

AN ANALYST'S AND USER'S GUIDE TO THE PASSIVE
SONAR MODEL IN THE NAVAL WARFARE
INTERACTIVE SIMULATION SYSTEM

by

Albert A. Tobin, Jr.

September 1984

Thesis Advisor:

Gary Porter

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An Analyst's and User's Guide to the Passive
Sonar Model in the Naval Warfare
Interactive Simulation System

by

Albert A. Tobin, Jr.
Lieutenant, United States Navy
B.S., United States Naval Academy, 1977

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ABSTRACT

This user's guide examines the passive sonar model used by the Naval Warfare Interactive Simulation System (NWISS). The processes by which passive sonar detections are made are discussed. The thesis includes an explanation of how to affect those processes in order to control the interaction and results of an NWISS ASW scenario. A method for determining a sonar system's figure of merit and estimating ranges of detection is presented for the benefit of the operator who prepares the scenario, as well as for the user. This method is primarily intended for use with NWISS in its tactical training role.

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I. INTRODUCTION

For centuries, military organizations have resorted to wargaming in order to train personnel and to evaluate tactics. In the past, actual troops, game boards, dice, umpires, etc., have been used to carry out a wargame. The advance of high technology, and the progress in the study of probability and modeling, have made it possible to use computers to simulate warfare. The Naval Warfare Interactive Simulation System (NWISS) is one such wargame.

NWISS is an extremely valuable system which can be used for tactical training, for tactical analysis, or for developmental research in evaluating new weapons systems if used properly. It is most useful as a tactical trainer because the operator has control over the scenario inputs and therefore can control the interactions within the wargame, as well as the results. These interactions and results may not reflect exact "real world" conditions, but can be made to come very close, based on past experiences or knowledge of previous outcomes. When the limitations of the wargame are known and are taken into account, NWISS can be used quite successfully as a tactical trainer.

In analysis of tactics and in developmental research, the use of NWISS is somewhat more limited. The requirements

to obtain satisfactory results are more stringent in these cases. It is more important to have "real world" results because conclusions based on other than "real world" results could have grave consequences or at the very least be wasteful of time and money. Therefore, it is imperative that a system being used for tactical analysis or developmental research be verified and validated prior to being used to ensure that the models utilized are sufficiently realistic for the application at hand.

In the Naval Warfare Interactive Simulation System, the passive sonar model determines detection between two elements, the detecting platform, and the target. The detecting platform is any platform with passive sonar capability such as a surface ship utilizing hull mounted sonar, a submarine utilizing a towed array, or an antisubmarine warfare (ASW) aircraft capable of monitoring passive sonobuoys. The target is any seagoing platform which can be detected by passive sonar. In many cases, a detecting platform may also be a target.

The passive sonar model in NWISS operates using the Monte Carlo method. That is, a probability of detection is computed which is subsequently compared to a random number drawn from a uniform (0,1) distribution (a number uniformly distributed between 0 and 1). The results of this comparison answers the question, Is the target detected?

The detection probability is computed each game minute, for each of three acoustic elements, for each sensor-target pair in the game within the maximum sonar range specified for the game (typically 120 nautical miles). The three acoustic elements are:

- a) Narrowband frequency signature.
- b) Emissions from active sonar.
- c) Broadband noise.

The passive sonar model computes the detection probability for each of the three acoustic elements associated with the target's underwater acoustic signal as a function of target source level, sonar performance, underwater ambient noise, and underwater acoustic propagation loss.

The NWISS operator, or persons preparing the wargame, can use the documentation and methodology described in this thesis in several ways. Primarily it will allow the operator to understand the passive sonar model so that he may prepare the antisubmarine warfare portion of the game more effectively and more efficiently. It will provide a method of producing desired sonar performance based on the training requirement by adjusting parameters appropriately. It allows the operator to check for reasonable or unreasonable results of the passive sonar encounter and identify parameters which need to be changed if the results

are unreasonable. It provides a method for determining the expected ranges of detection for a specific passive sonar encounter.

For the trainee, this documentation provides a comprehensive look at the fundamentals of passive sonar detection. It provides a review of the passive sonar equation and explains each of the parameters concisely. The trainee can use the method described to determine the expected range of detection in order to compute the mean detection range (MDR) and subsequently plan for optimum ASW coverage in a particular area, against a specific target.

The content of this thesis is arranged to give the reader the background necessary to understand the passive sonar model in NWISS and then apply that background knowledge. Chapter II discusses NWISS briefly, relating the basics of setting up a wargame. Chapter III introduces the passive sonar equation. Chapter IV is the heart of the thesis; it describes in detail the passive sonar model used in NWISS and its function in passive sonar detection. Chapter V provides a logical step by step explanation of the NWISS passive sonar detection process. Chapter VI introduces the figure of merit and how it can be applied. Chapter VII offers conclusions and recommendations, and Appendix A discusses the environment files.

II. NWISS

The Naval Warfare Interactive Simulation System is supported by the Interim Battle Group Tactical Trainer/Computer Support Facility (IBGTT/CSF) located at the Naval Ocean Systems Center in San Diego, California. In June 1982, NWISS was designated by the CNO to be utilized for battle group tactical training by Tactical Training Group Pacific (TACTRAGRUPAC), and by Pacific Fleet Commands until such time as the Enhanced Naval Warfare Gaming System becomes available (approximately 1986).

TACTRAGRUPAC employs NWISS as part of its Staff Team Tactical Training (STTT) course. STTT is a four week course designed to provide Battle Group Commanders and their staffs with the most up to date tactical training available. Three days of the course are dedicated to using NWISS. The Battle Group Commander participating in STTT selects a scenario which will meet the training requirement of the battle group. Once the scenario is selected and the orders-of-battle identified, an NWISS game can be created.

In 1983, NWISS was installed at the Wargaming, Analysis, and Research (WAR) Lab at the Naval Postgraduate School, Monterey, California. There it is used to expose military officers to the limitations and capabilities of computer

wargaming. NWISS is taught as part of a simulation and wargaming course offered to Operations Analysis, Antisubmarine Warfare, Command, Control and Communications, Electronic Warfare, Space Operations, and other curricula.

In order to prepare a game, the operator invokes three computer processes, BUILD, FORCE, and GAME. BUILD constructs a database which specifies the characteristics which define the types of ships, submarines, aircraft, shorebases, satellites, sensors, and weapons to be used during the game. FORCE specifies the force elements and initial scenario conditions to be used. GAME actually executes the scenario and responds to player inputs.

The BUILD process allows the operator to review the database characteristic files of all object types used in NWISS (ships, submarines, aircraft, etc.). BUILD also allows the operator to add, delete, or modify any characteristic parameters as deemed necessary. If a desired game object type is not included, BUILD can be used to specify the characteristics of new object types. Normally, BUILD will already have been used to create a file of game object types which could then be used for different scenarios.

The FORCE process provides the operator with the means for building a specific scenario into the game. This is accomplished by using the generic characteristic files in BUILD such as that of a ship class, and assigning a specific

name to that ship. The FORCE process also allows for the input of initial position, course and speed of the forces, environmental sonar regions (see Appendix A), weather conditions, emcon plans, command and communications hierarchy, as well as other initial conditions. As with the BUILD process, FORCE allows the operator to review, add, delete, or modify entries as necessary.

The GAME process provides the interactive aspects of NWISS. It is invoked just prior to game start and it is within this process that the game is executed.

The dynamics of the game are created and maintained in an area of computer memory and in a file called the blackboard. The blackboard is a global area and maintains the status of all game objects as the game progresses. The blackboard contains such parameters as the speed of ships or subs, and the range between detecting platform and target. For a more detailed description of how to run NWISS, the reader is referred to the user's guides in the bibliography.

To provide for the various functions of the wargame the Naval Warfare Interactive Simulation System uses a variety of models. Most of these are designed to model the physical situations using mathematical equations and rely on the database characteristic files to provide the values for the variables. This thesis examines the passive sonar model in NWISS which uses the passive sonar equation to determine the probability of passive sonar detection.

III. THE PASSIVE SONAR EQUATION

NWISS uses the passive sonar equation in the passive sonar model to compute signal excess and subsequently to determine whether passive detection does or does not occur. This chapter introduces the passive sonar equation and provides the reader with a brief review of the fundamentals of passive sonar detection. It also serves as a reference for Chapter IV, which describes the passive sonar model of NWISS and the parameters it employs.

The passive sonar equation is primarily a specialized mathematical statement of the law of conservation of energy. The equation provides a working relationship that ties together the effects of the medium, the target, the equipment, and the operator. In NWISS, the use of the passive sonar equation serves an important practical function, namely that of predicting passive sonar performance.

In developing the passive sonar equation, the following thought processes must be taken:

- a) Consider that the target radiates a certain acoustic energy intensity level. The intensity level of this acoustic energy is a function of the frequency or band of frequencies radiated. This radiated level is called target source level (SL).

- b) As the acoustic signal radiates outwardly from the source the intensity level is diminished due to any of the following effects of the ocean environment: spreading, ray path bending, absorption, reflection, and scattering. This decrease in intensity is called transmission loss (TL). Hence, the signal arriving at the detecting sonar array is represented by the target source level minus the transmission loss, $(SL - TL)$.
- c) The sonar array is subject to the background noise in the ocean. Background noise can be divided into two categories, self-noise (SN) and ambient noise (AN). Self-noise is the parameter representing that part of the background noise due to the effects of the machinery noise of the detecting platform and of the hydrodynamic flow past the array hydrophones. Ambient noise represents that part of background noise due to the effects of the sea state, shipping, and biologics or any other elements that introduce sound into the ocean. Background noise level (NL) is usually measured by omnidirectional hydrophones. Directional sonar arrays, however, will discriminate against omnidirectional noise. The measure of the advantageous effect of the array directivity is called the directivity index (DI). Since

directivity decreases the effect of background noise, the actual background noise apparent to the sonar array is the noise level minus the directivity index (NL - DI).

- d) Consider now the capability of the sonar array and the ability of the operator, to detect an arriving signal. The measurement of this capability is called the recognition differential (RD). Recognition differential is defined as the signal received minus the apparent noise level required in order that an operator can detect a target on 50 percent of those occasions for which a target presents itself. In terms of the previously discussed parameters, the recognition differential is:

$$RD = SL - TL - (NL - DI) \quad (3-1)$$

which is the passive sonar equation.

By placing the range independent terms on one side of the passive sonar equation it becomes more meaningful and useful:

$$TL = SL - NL - RD + DI. \quad (3-2)$$

When a value for transmission loss is available, either through direct measurement or through prediction, a term known as signal excess can be computed:

$$SE = SL - NL - RD + DI - TL. \quad (3-3)$$

By definition, there exists a 50 percent probability of detection when the transmission loss equals the right hand side of Equation 3-2. Hence, in that case, the signal excess equals zero.

If the signal excess is greater than zero, then the probability of detection is greater than 50 percent. If the signal excess is less than zero, the probability of detection is less than 50 percent. This relationship between the signal excess and probability of detection provides the basis for the use of Equation 3-3 in the passive sonar model of NWISS.

IV. THE PASSIVE SONAR MODEL

To prepare an NWISS game in which antisubmarine warfare is to be conducted, it is necessary to thoroughly understand how the passive sonar model operates. The model utilizes a representation of the passive sonar equation described in Chapter III. It draws parameters from the blackboard, the database characteristic files, and the environment file. Familiarization with these parameters and how they are incorporated into the passive sonar model enable the operator to prepare the ASW portion of an NWISS game. For the player, while a thorough understanding of the passive sonar model is not required, familiarization would be advantageous in the formulation of tactics.

The general passive sonar equation used by the passive sonar model in NWISS is:

$$SE = SL - NL - RD + DI - TL \quad (4-1)$$

where,

SE = Signal Excess

SL = Target Source Level

TL = Transmission Loss

NL = Noise Level

RD = Recognition Differential

DI = Receiver Directivity Index

The above listed parameters are all in units of decibels. The passive sonar equation presented above is modified when used in detecting broadband noise to account for a bandwidth correction factor. This modification will be discussed under the section "Detection of Broadband Noise". In addition to modeling passive detection, the passive sonar model used in NWISS contains algorithms to determine submarine contact classification, and target motion analysis.

The following discussion will examine the parameters used by the passive sonar model with respect to each acoustic element and how to locate them in their respective data files.

A. DEFINITION OF PARAMETERS

The numerical data used by the passive sonar model is drawn from the database characteristic files, the environmental files, and the blackboard. The passive sonar model converts all the information necessary into the parameters used by the passive sonar equation to determine signal excess.

There are advantages and disadvantages to the use of tabled data as opposed to the use of equations to model the various parameters. The advantage in using table data is primarily that computer processing time is decreased, however, in the NWISS passive sonar model the use of tabled

data gives the operator the flexibility to adjust the parameters to affect the results of a passive sonar encounter. A major disadvantage is that by using tabled data for the parameters, all of the factors that affect the parameters are not taken into account. For example, directivity index is a function of frequency as well as direction but the tabled value for directivity index is only a function of direction.

In the environment file, ambient noise is presented as a function of frequency only, while it is also affected by shipping, weather, depth of the sensor, and biologics. Narrowband frequency target source levels are tabled according to frequency only, however, the source level is also a function of target speed.

In using NWISS as a tactical trainer, the advantages outweigh the disadvantages. However, using NWISS for analysis or for developmental research, the operator must consider the deficiencies of using the table parameters. The results of any analytical work or research must be carefully studied to determine whether the deficiencies in parameters significantly affect the validity of the model.

1. Database Characteristic Files

The following elements which contribute to passive sonar detection have characteristic data files:

- 1) Ships/submarines
- 2) Sonar systems
- 3) Sonobuoys

a. Ships/Submarines

The characteristic data of ships and submarines is contained in a file titled "Ship Class Characteristics" in the BUILD process. Figures 4-1 and 4-2 show example characteristic data files of a ship and submarine respectively. The parameters in the files utilized by the passive sonar model are the terms BBN, NBN, and SONAR.

The line labeled BBN contains the broadband noise level of the ship or submarine specified. The data on this line represents the values of the target source level of the representative ship or sub when its broadband noise is considered for detection. There is one line labeled BBN which requires six data entries. The data is arranged from left to right corresponding to target speeds of 5 kts., 10 kts., 15 kts., 20 kts., 25 kts., and 30 kts., respectively.

The line labeled NBN contains the narrowband frequency of the specific ship or submarine followed by the target source level. There may be up to six lines labeled NBN, each one identifying a separate narrowband frequency and source level. The data in the NBN line is used when considering narrowband signature detection of the respective ship or submarine, and represents the target source level in the passive sonar equation.

CLASS	SSHIP					
CAT	SURF					
TYPE	FF					
VMAX	27					
XSECT	31					
HDG	GYRO					
SPD	PTLOG					
CLRNG	15					
DTRNG	21					
TRKS	75					
BBN	128	140	144	163	160	165
NAV	SRN12					
LCHRT	1					
RECRT	1					
WAVE	20					
LACOM	20					
LASEN	20					
LAWPN	30					
LAFLD	5					
LASPD	10					
LAAJR	10					
RBOC	2	48				
NBN	91	144				
DECM	YES					
BLIP	YES					
RDESM	SPS10	75				
RDESM	SPS40	90				
RDESM	WLR1	70				
RDESM	SLR12	50				
RDESM	SPG53	80				
RDESM	LN66	90				
RDESM	MK115	60				
RDESM	URD4	60				
SONAR	PSDN1					
SONAR	ASDN1					
COMMS	UHF	80				
COMMS	HF	80				
COMMS	VHF	100				
MISS	HRPON	4				
BUOY	SSQ53	SONO	300			
BUOY	SSQ47	SONO	200			
WEAP	SSPRO	SAM	8			
WEAP	G554	GUN	600			
WEAP	MK46A	TORP	20			
WEAP	ASROC	TORP	12			
WEAP	MK46	TORP	22			
AIR	SH2F	1				

Figure 4-1. Database Characteristic File of a Ship

CLASS	SSUB					
CAT	NSUB					
TYPE	SSGN					
VMAX	22					
XSECT	22					
HDG	GYRO					
SPD	PTLOG					
CLRNG	6					
DTRNG	10					
TRKS	75					
BBN	137	139	141	143	145	147
DRATE	250					
KEEL	30					
PSCOP	60					
DR	SINS					
OMEGA	LWSPT					
NBN	300	145				
NBN	585	139				
RDESM	SNPTR	20				
RDESM	BRKSP	60				
SONAR	PSO2					
SONAR	ASO2					
COMMS	HF	90				
COMMS	UHF	90				
MISS	SSN7	8				
NAV	NAVST					
TORP	ET80	32				
WIRES	3					

Figure 4-2. Database Characteristic File of a Submarine

The line labeled SONAR specifies the particular sonar system used by the ship or submarine. Each line has only one entry, there may be as many as six SONAR lines, each identifying the available sonar systems for the particular ship or submarine of interest. This line serves as an index to the sonar characteristic data file described below.

b. Sonars

The characteristic data of sonar systems is contained in a file titled "Sonar Characteristics" in the BUILD process. Figures 4-3 and 4-4 show example characteristic data of an active sonar and a passive sonar, respectively. Since this thesis is concerned with the passive sonar system as the detecting sensor, all of the parameters listed with the exception of CFREQ in the passive sonar system characteristic data file are used by the passive sonar model. Because an active system is a source for passive detection, only the terms CFREQ and LEVEL in the active sonar characteristic file are of interest in considering passive sonar detection.

>NAME	ASON2
>CAT	AHULL
>CFREQ	3000
>LEVEL	240
MNFAL	4320
MNRPR	1440
MODE	DP
MODE	CZ

Figure 4-3. Database Characteristic File of an Active Sonar System

NAME	PSDN1					
CAT	PHULL					
CFREQ	2000					
LFREQ	300					
HFREQ	2500					
HZBW	8					
VERBW	45					
BRERR	2					
RD	-12					
DI00	21	21	21	21	21	21
DI60	21	21	21	21	21	21
DI120	21	21	21	10	0	-10
BBN	64	65	69	79	84	84
NBN1	300	300	300	300	300	300
NBN2	300	300	300	300	300	300
NBN3	300	300	300	300	300	300
NBN4	300	300	300	300	300	300
NBN5	300	300	300	300	300	300
NBN6	300	300	300	300	300	300
NBN7	300	300	300	300	300	300
NBN8	300	300	300	300	300	300
NBN9	300	300	300	300	300	300
NBN10	300	300	300	300	300	300
NBN11	73	77	77	80	82	300
NBN12	56	62	63	67	67	300
NBN13	46	53	54	59	62	300
NBN14	41	45	45	51	57	300
NBN15	39	41	43	51	57	300
NBN16	37	38	42	52	57	300
NBN17	36	37	41	51	57	300
NBN18	300	300	300	300	300	300
NBN19	300	300	300	300	300	300
NBN20	300	300	300	300	300	300

Figure 4-4. Database Characteristic File of a Passive Sonar

The lines labeled LFREQ and HFREQ define the low and high frequency limits of the system, respectively. There is one data entry for each line. The particular sonar system is capable of detecting frequencies which lie between the values specified by LFREQ and HFREQ inclusive.

The lines labeled HZBW and VERBW define the horizontal and vertical beamwidths of the system, respectively. Each line contains only one data entry. The sonar system considered is capable of detecting targets that lie in the volume defined by the angles specified by HZBW and VERBW.

The line labeled BRERR indicates the standard deviation used in reporting the bearing of the contact. The data is not used in the detection process.

The line labeled RD defines the recognition differential of the system. There is one entry in this line, typically a negative number. The value of RD is used directly in the passive sonar equation to compute signal excess.

The lines labeled DI00, DI60, DI120, define the directivity index of the sonar system. Each line has six data entries which correspond to the target angle off the bow of the detecting platform. Each line covers a sixty degree sector of which each entry corresponds to ten degrees. The data entry specifies the value used for DI in the passive sonar equation.

The line labeled BBN in the sonar characteristic data file defines the self noise of the system when it is used in detecting broadband noise. There are six data entries in the line corresponding to detecting platform speed. Arranged from left to right, the entries define the self noise of the system for speeds of 5 kts., 10 kts., 15 kts., 20 kts., 25 kts., and 30 kts., respectively. The value specified by the data is used in the computation of the noise level.

The lines labeled NBN1 through NBN20 define the self noise of the system when it is detecting a narrowband signature. Each line corresponds to one of the 20 frequencies listed in the environment file and shown in Table 4-1. Lines NBN1 through NBN20 each have six entries corresponding to the detecting platform speed, as with the BBN line described in the previous paragraph.

TABLE 4-1

Frequencies Corresponding to Lines NBN1 Through NBN20

NBN1	. . . . .	10 Hz	NBN11	. . . . .	315 Hz
NBN2	. . . . .	15 Hz	NBN12	. . . . .	630 Hz
NBN3	. . . . .	20 Hz	NBN13	. . . . .	900 Hz
NBN4	. . . . .	30 Hz	NBN14	. . . . .	1250 Hz
NBN5	. . . . .	40 Hz	NBN15	. . . . .	1600 Hz
NBN6	. . . . .	60 Hz	NBN16	. . . . .	2000 Hz
NBN7	. . . . .	80 Hz	NBN17	. . . . .	2500 Hz
NBN8	. . . . .	100 Hz	NBN18	. . . . .	3500 Hz
NBN9	. . . . .	125 Hz	NBN19	. . . . .	5000 Hz
NBN10	. . . . .	250 Hz	NBN20	. . . . .	10000 Hz

c. Sonobuoys

The characteristic database describing sonobuoys is contained in a file titled "Sonobuoy Characteristics" in the BUILD process. Figure 4-5 shows the database characteristic file of a sonobuoy. There are only three lines included in the characteristic database file of sonobuoys which are different from those in the "Sonar Characteristic" described above: LIFE, MNFAL, and OMNI. LIFE indicates the amount of time that the sonobuoy is operational. MNFAL defines the mean failure rate, and OMNI specifies whether the sonobuoy is omnidirectional.

2. Environment File

The environment file contributes three parameters to the passive sonar detection process: Sonic layer depth, ambient noise, and transmission loss. This section will describe each of these three terms. For a more detailed explanation of the environment files, see Appendix A. Samples of environment files are also contained in Appendix A.

The sonic layer depth is the first entry in the environment file. It represents the depth at which the sound speed gradient shifts from positive to negative defining the floor of surface duct. It is the value specified by the sonic layer depth that is used in determining the source/receiver layer geometry. If the

NAME	SONO1						
CAT	PASS						
LIFE	180						
CFREQ	300						
LFREQ	10						
HFREQ	2400						
HZBW	12						
VRBW	20						
BRERR	5						
RD	-5						
DI00	2	2	2	2	2	2	2
DI60	2	2	2	2	2	2	2
DI120	2	2	2	2	2	2	2
MNFAL	1000						
OMNI	NO						

Figure 4-5. Database Characteristic File of a Passive Sonobuoy

source (target) and the receiver (detecting platform) are both shallower than the sonic layer depth, the source/receiver layer geometry is said to be IN layer. If they are both deeper than the sonic layer depth, the source/receiver layer geometry is said to be DEEP. If the source is deeper and the receiver is shallower than the sonic layer depth or vice versa, the source/receiver layer geometry is a CROSS layer one.

The layer geometries correspond to the columns in the transmission loss tables labeled IN, CROSS, and DEEP. In the case of towed array sonars, the hydrophones are modeled at a depth of 300 feet below the depth of the towing

platform. Hull mounted sonars are modeled at the depth of the detecting platform. In order to avoid micro-management of assets, sonobuoys were modeled with only one depth setting, 300 feet. This factor also contributes to the inflexibility of the NWISS passive sonar model in the analysis or developmental research role.

The values for ambient noise are in the sixth line of the environment file labeled Ambient Noise. There are 20 entries which correspond to the 20 frequencies in the previous line. The frequency of interest being detected is used to determine the value of ambient noise used in calculating the noise level term in Equation 4-1. The value of ambient noise is read directly below the frequency nearest the frequency of interest, using the higher frequency, if the frequency of interest is exactly between two listed frequencies.

The transmission loss tables are labeled Propagation Loss Data and make up about 85% of the environment file. The data is tabled according to frequency, source/receiver layer geometry, and range from the source to the receiver. That is, there is a single value of transmission loss for each of the 20 frequencies listed, for each of the three possible source/receiver layer geometries, and for the specific range between source and receiver from one to 120 nautical miles in 1 NM increments. To determine the value

of transmission loss used in Equation 4-1 refer to the propagation loss data table under the frequency nearest the frequency of interest, using the higher frequency, if the frequency of interest is exactly between two listed frequencies. In that table, select the column corresponding to the appropriate source/receiver layer geometry and read the value of the transmission loss across from the appropriate range.

Each parameter listed in the NWISS passive sonar equation has been described and their location within the NWISS architecture discussed. The following sections will describe the calculations involved in the detection of each acoustic element. Narrowband frequency signature detection will be discussed first, followed by detection of active sonar emissions, and broadband noise detection. The final section in this chapter will describe how the probability of detection is determined.

B. DETECTION OF NARROWBAND FREQUENCY SIGNATURE

The narrowband frequency signature of a potential passive sonar contact is due to the domination of the particular frequency or tonal in the noise radiated from the target. In NWISS a ship or submarine may be assigned up to six narrowband frequencies. The narrowband frequency used for a particular calculation of signal excess will be referred to as the narrowband frequency of interest.

1. Target Source Level

The target source level (SL) is specified in the characteristic file of the target. It is located in a line labeled NBN (there may be as many as six lines labeled NBN). In the case of diesel submarines, the line labeled NBN applies when the submarine is submerged running on batteries, and the line labeled NBD applies when the submarine is snorkeling. The first number in the line is the narrowband frequency of interest. The second number is the target source level. Note that the target source level used in the passive sonar model for narrowband signature detection is solely a function of the narrowband frequency of interest, and not speed of the target.

2. Transmission Loss

The value of transmission loss (TL) is taken from the transmission loss tables of the environment file corresponding to the location of the detecting platform (See Appendix A for sample environment file). To determine the value of the transmission loss, enter the table corresponding to the frequency nearest the narrowband frequency of interest, using the higher frequency, if the narrowband frequency of interest is exactly between two tabled frequencies. Next, you identify the column corresponding to the appropriate source/receiver layer geometry, and read the value of transmission loss down the

column, opposite the range. Transmission loss in the passive sonar model of NWISS, is a function of four elements: 1) detecting platform location, 2) frequency of interest, 3) source/receiver layer geometry, and 4) range from the target to the detecting platform.

3. Noise Level

The noise level (NL) is computed as the power sum of the ambient noise (AN) and the receiver self noise (SN), using the following equation:

$$NL = 10 \log [10^{(AN/10)} + 10^{(SN/10)}] \quad (4-2)$$

Ambient noise is taken from the environment file corresponding to the location of the detecting platform. The value for ambient noise is located in the line labeled AMBIENT NOISE. To determine the ambient noise used to compute the signal excess, read the value directly beneath the frequency nearest the narrowband frequency of interest, using the higher frequency, if the narrowband frequency of interest is exactly between two listed frequencies.

Self noise is specified in the characteristic data file of the passive sonar system used by the detecting platform. The characteristic data file of the detecting platform identifies the passive sonar system in a line labeled SONAR. To locate the value of self noise in the

sonar system characteristic data file, refer to the portion of the file labeled NBN1 through NBN20. NBN1 through NBN20 correspond to the 20 frequencies described in Table 4-1 and also found in the environment file. Find the line corresponding to the frequency nearest the narrowband frequency of interest, using the higher frequency, if the narrowband frequency of interest is exactly between two listed frequencies, and read the value of self noise from the column corresponding to the speed nearest the speed of the detecting platform. The columns correspond to speeds of 5 kts., 10 kts., 15 kts., 20 kts., 25 kts., and 30 kts., respectively reading from left to right. For sonobuoys and for ships/submarines doing 0 kts., 1 kt., or 2 kts., the self noise is zero.

Due to the nature of Equation 4-2 the value of the noise level will never be less than the larger of ambient noise and self noise, and will never be more than 3 dB greater than the larger of the ambient noise and self noise. The latter occurs when ambient noise equals self noise. The former occurs when the difference between ambient noise and self noise is more than 20 dB. In summary, the noise level in NWISS is a function of three elements: 1) detecting platform location, 2) frequency of interest, and 3) detecting platform speed.

4. Directivity Index

Directivity Index (DI) is located in the characteristic data file of the passive sonar system used by the detecting platform. The sonar system is identified in the characteristic data file of the detecting platform in the line labeled SONAR. Directivity index is read from the lines in the sonar system characteristic data file labeled DI00, DI60, and DI120. Those lines include the values of directivity index corresponding to target angles off the bow of the detecting platform. DI00 contains values for target angles between 0 and ± 59 degrees relative (the first column being 0 and ± 9 degrees, second column being ± 10 to ± 19 degrees, etc.). Similarly, DI60 contains values for target angles between ± 60 degrees and ± 119 degrees relative. While DI120 contains the values for target angles between ± 120 degrees and ± 180 degrees relative. The directivity index used for calculating the signal excess in NWISS is a function of only the target angle off the bow of the detecting platform.

5. Recognition Differential

The recognition differential (RD) is located in the characteristic data file of the passive sonar system used by the detecting platform in the line labeled RD. The sonar system is identified in the characteristic data file of the detecting platform in a line labeled SONAR.

C. DETECTION OF ACTIVE SONAR EMISSIONS

In the detection of active sonar emissions, the passive sonar model includes the signal output by underwater communications equipment as well as the acoustic signal of an active sonar "pinging". The frequency detected is the frequency of the underwater transmission or the center frequency of the active sonar system on the target.

The underwater communication equipment is identified from the target characteristic data file in a line labeled COMMS. The frequency of the transmitted signal is found in the characteristic data file of the underwater communication system specified in the line labeled FREQ. The active sonar system of the target is specified in the characteristic data file of the target in a line labeled SONAR. The center frequency of the active sonar acoustic signal is found in the characteristic data file of the active sonar system in the line labeled CFREQ. The applicable frequency will be referred to as the active emission frequency of interest.

1. Target Source Level

Target source level (SL) is specified in the characteristic data file of the active sonar system used by the target. The characteristic data file of the target identifies the active sonar system in a line labeled SONAR. The target source level is found in the characteristic data file of the active sonar system in the line labeled LEVEL.

2. Transmission Loss

The value of transmission (TL) is taken from the transmission loss tables of the environment file corresponding to the location of the detecting platform. To determine the value of the transmission loss, enter the table corresponding to the frequency nearest the active emission frequency of interest, using the higher frequency, if the active emission frequency of interest is exactly between two tabled frequencies. Next, identify the column corresponding to the appropriate source/receiver geometry, and read the value of transmission loss down the column, opposite the range. In its application to the passive sonar model of NWISS, the transmission loss is a function of four elements: 1) detecting platform location, 2) frequency of interest, 3) source/receiver geometry, and 4) range from the target to the detecting platform.

3. Noise Level

The noise level (NL) in the case of detecting active emissions is computed in the same manner as in the narrow-band signature detection. See "Noise Level" on page 33.

4. Directivity Index

Directivity index (DI) is located in the same way for detection of active emission as it is for detecting narrowband signature. See "Directivity Index" on page 35.

5. Recognition Differential

The procedure for locating the recognition differential (RD) is identical for all three acoustic elements. See "Recognition Differential" on page 35.

D. DETECTION OF BROADBAND NOISE

Broadband noise is that noise radiated from the target which has a continuous noise spectra. That is, the signal level is a continuous function of frequency as opposed to discontinuous as the case with narrowband signals. To detect broadband noise using the passive sonar model in NWISS a mean frequency is specified. That mean frequency will be referred to as the broadband noise frequency of interest. At the time of this writing, the broadband noise frequency of interest used in the NWISS passive sonar model is 2000 Hz.

Associated with the detection of broadband noise is the bandwidth correction to the passive sonar equation. The bandwidth in detecting broadband noise using the passive sonar model in NWISS is 500 Hz. The bandwidth correction applies to the target source level and to the detecting platform self noise. The correction is calculated using the following expression:

$$C = -10 \log W \quad (4-3)$$

where,

C = bandwidth correction

W = bandwidth

Since the bandwidth in NWISS is fixed at 500 Hz, from Equation 4-3 the correction is -27 dB. The passive sonar equation modified for the detection of broadband noise is then:

$$SE = SL - NL - RD + DI - TL - 27 \quad (4-4)$$

The correction as applied to self noise will be covered in the discussion of noise level.

1. Target Source Level

The target source level (SL) is located in the characteristic data file of the target in the line labeled BBN. In the case of a diesel submarine the line labeled BBN applies to the submarine submerged operating on batteries. If the submarine is surfaced and snorkeling the line labeled BBD applies. The line is arranged corresponding to the speed of the target, from left to right with target source level values for 5 kts., 10 kts., 15 kts., 20 kts., 25 kts., and 30 kts., respectively. To obtain the target source level used in the calculation of the signal excess, read the entry corresponding to the speed nearest the target speed. For a target doing 0 kts., 1 kt., or 2 kts., the target source level is zero.

2. Transmission Loss

The procedure for locating the value of transmission loss used in calculating the signal excess when detecting

broadband noise is identical to that used when detecting narrowband noise with one exception. Instead of using the narrowband frequency of interest use the broadband noise frequency of interest which is 2000 Hz.

3. Noise Level

To compute noise level in the case of broadband noise detection, the bandwidth correction must be taken into account. The equation used is:

$$NL = 10 \log [10^{(AN/10)} + 10^{((SN-27)/10)}] \quad (4-5)$$

Ambient noise and self noise are located in the same manner for broadband noise detection as for the other two acoustic elements. See "Noise Level" on page 33.

4. Directivity Index

The procedure for locating the directivity index (DI) in the case of detecting broadband noise is identical to that of when detecting narrowband signature. Refer to "Directivity Index" on page 35.

5. Recognition Differential

The procedure for locating the recognition differential when detecting broadband noise is identical to that when detecting narrowband signature. Refer to "Recognition Differential" on page 35.

E. DETERMINING THE PROBABILITY OF DETECTION

Once the passive sonar model computes the signal excess, it then converts it to a probability of detection. The probability of detecting a passive sonar contact is treated as a normal distribution with a mean equal to zero and standard deviation equal to 2 dB. A bell curve representation of signal excess is shown in Figure 4-6.

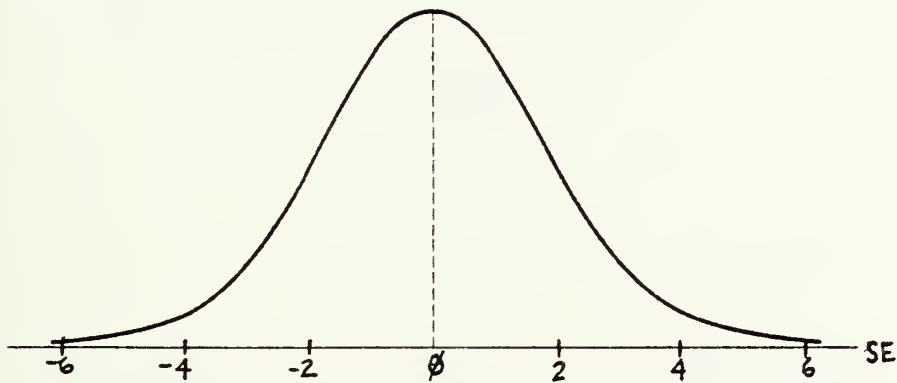


Figure 4-6. Normal Curve Representation of Signal Excess

The signal excess is then converted to a standard normal Z score using the following equation:

$$Z = (SE - \mu) / \sigma \quad (4-6)$$

where,

Z = Standard normal Z score

SE = Signal excess

μ = Mean signal excess

σ = Standard deviation of the signal excess

So that the Z score for the computed signal excess is:

$$Z = SE/2 \quad (4-7)$$

The Z score is then converted to a probability of detection (P_d) from a table of cumulative standard normal distribution. Figure 4-7 shows the bell curve representation of the Z score mapped against the signal excess.

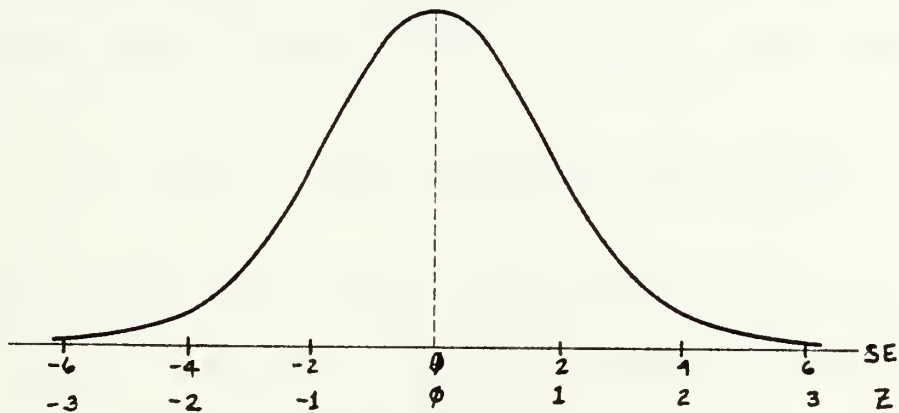


Figure 4-7. Normal Curve Representation of Z Score

The probability of detection is then tested against a random number to determine whether the target is detected or not detected. Using a pseudo-random number generator, the computer simulates drawing a number from the uniform zero to one distribution. If the $U(0,1)$ random number is less than the computed P_d , the target is detected, otherwise it is not detected. There are two cases in which no test between P_d

and a random number is performed. If the Z score is greater than or equal to 3.0 then a detection is made without testing against a random number. If the Z score is less than or equal to -3.0, there is also no test against a random number and there is no detection.

In addition, no detection is reported for each of the following cases:

- a) The detecting sonar is a towed array and the platform employing the array has not maintained a steady course for a time equal to 0.02 times the array cable length divided by the platform speed:

$$t = (0.02 \times \text{Cable Length}) / \text{Platform Speed} \quad (4-8)$$

- b) The target true bearing is the same as the true bearing of another detected broadband source with a greater signal excess.
- c) The frequency is the same as the frequency of another detected narrowband tonal, the true bearing of which is within one-half beamwidth of the source of this frequency, and the other source has a higher signal excess.

As shown in Figure 4-6, the test of P versus a random number applies only to signal excesses between -6.0 and 6.0. This is because of the choice of 2 dB for the standard

deviation of the signal excess. The standard deviation of 2 dB was chosen because it provided more consistent detections than a higher standard deviation and yet did not provide "cookie cutter" results using a lower standard deviation. The standard deviation controls the range window of detections.

As an example of converting a signal excess to a probability of detection, consider the following. Suppose the computed signal excess for a given passive sonar encounter is 3.74. Using Equation 4-7, the Z score is 1.87. From a table of cumulative standard normal distribution, a Z score of 1.87 represents a probability of detection of 0.9693. That is, for a signal excess of 3.74, the probability of detecting the target is 96.93 percent. Due to the symmetry of a normal distribution, a computed signal excess of -3.74 would yield a probability of detection of $(1 - 0.9693)$ or 0.0307. Therefore, if the computed signal excess was -3.74, the probability of detecting the target is 3.07 percent.

V. THE DETECTION PROCESS

To perform the detection computations required, the passive sonar model used in NWISS makes use of the standard passive sonar equation. This is accomplished by retrieving the independent variables to be used in the equation from the game's various data files and simply performing an algebraic summation resulting in the signal excess. There is a logical sequence of steps that is followed in determining whether or not a passive detection is made. A flow diagram is provided to show the detection process. See Figures 5-1 through 5-11.

The diagram outlines the detection process for only one pair of opposing platforms. This process takes place within NWISS each game minute and for all the possible combinations of platforms with passive sonar capability versus non-own force surface or submarine platforms that are involved in a particular game scenario. The diagram is not a true computer program flow diagram since it was not taken directly from the source code of the passive sonar model but it is a logically accurate representation of the source code.

The objective of the passive sonar model is to determine whether or not there is passive sonar contact in any of the

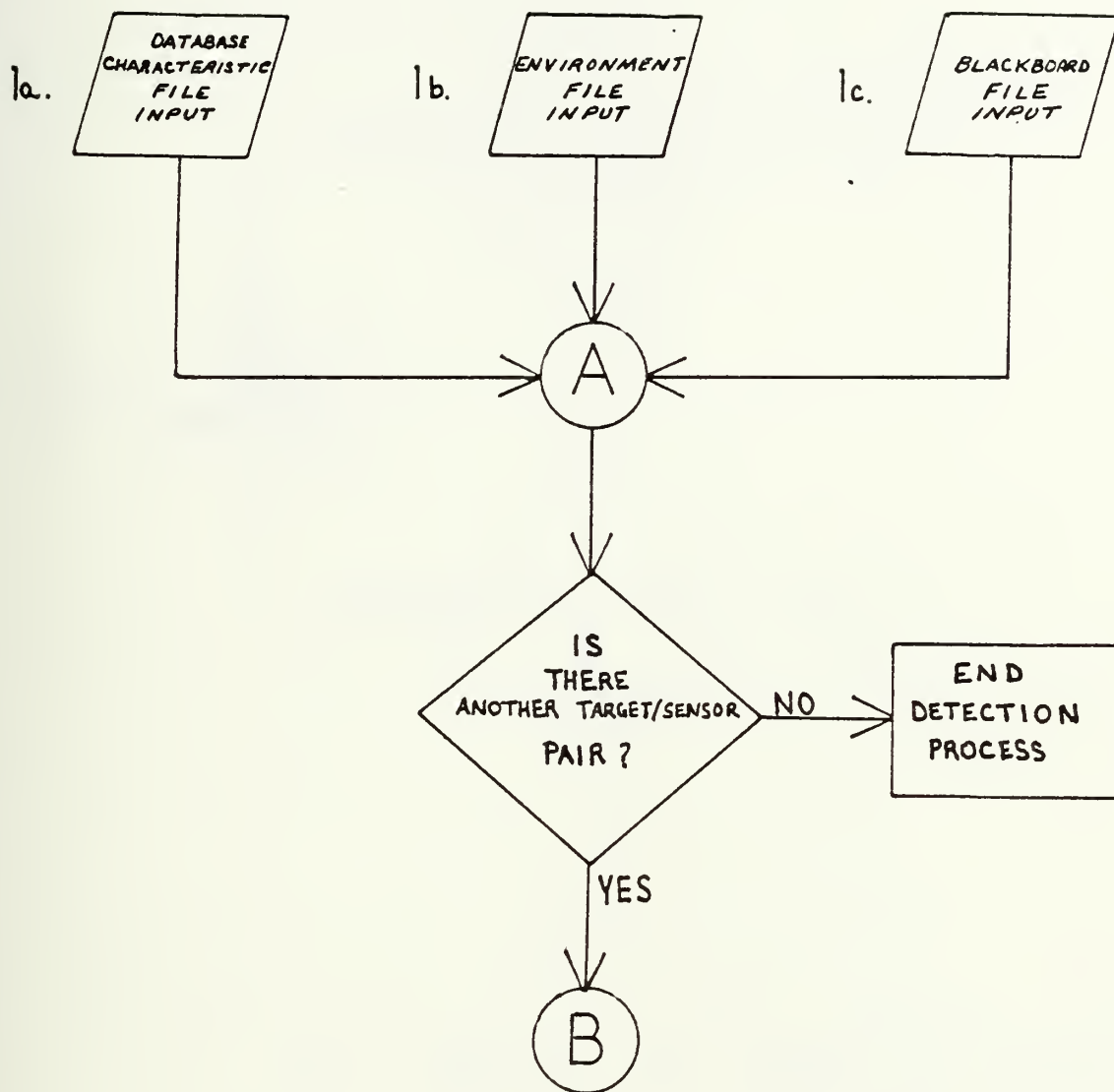


Figure 5-1. Steps 1a, 1b, and 1c

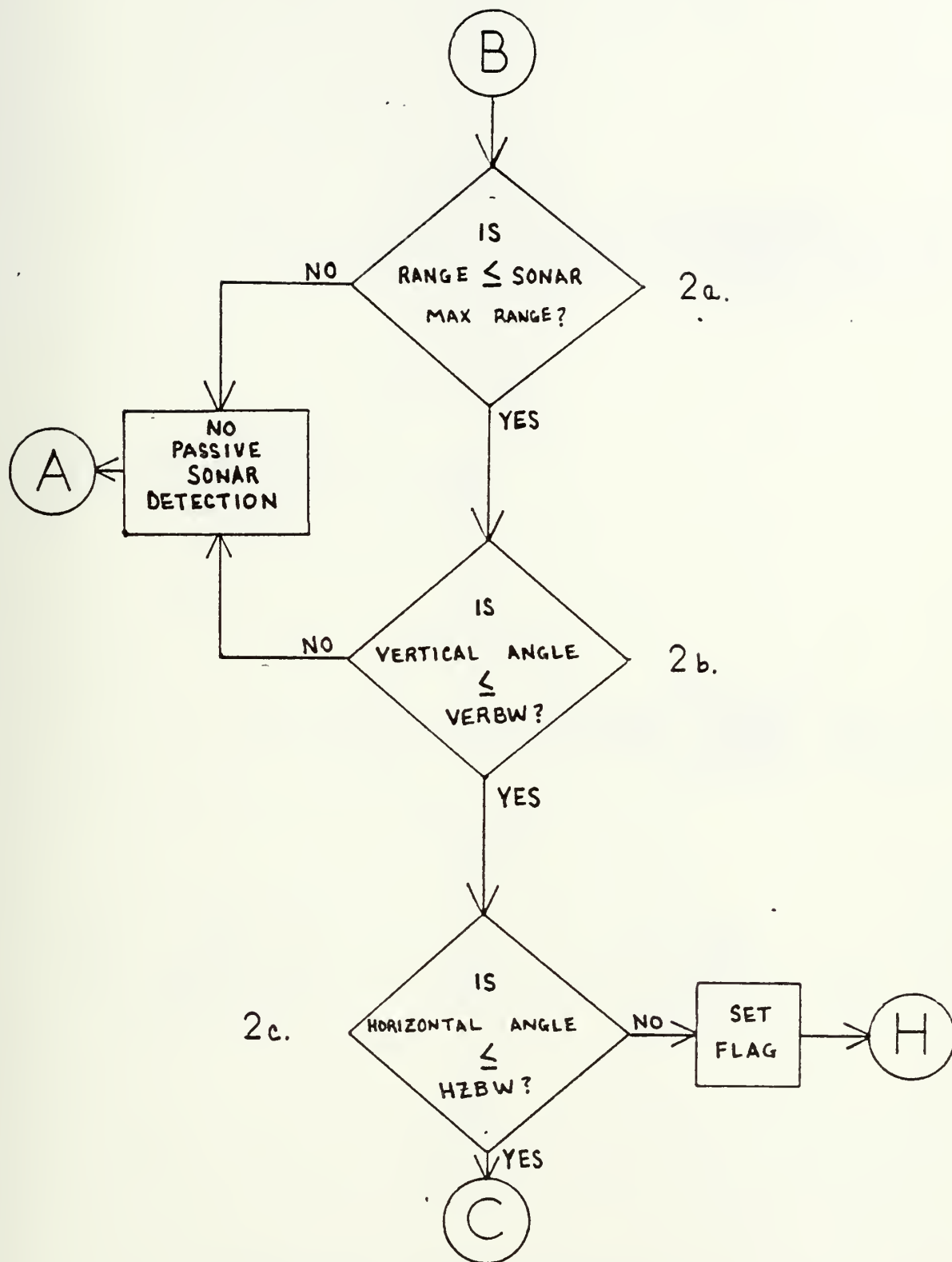


Figure 5-2. Steps 2a, 2b, and 2c

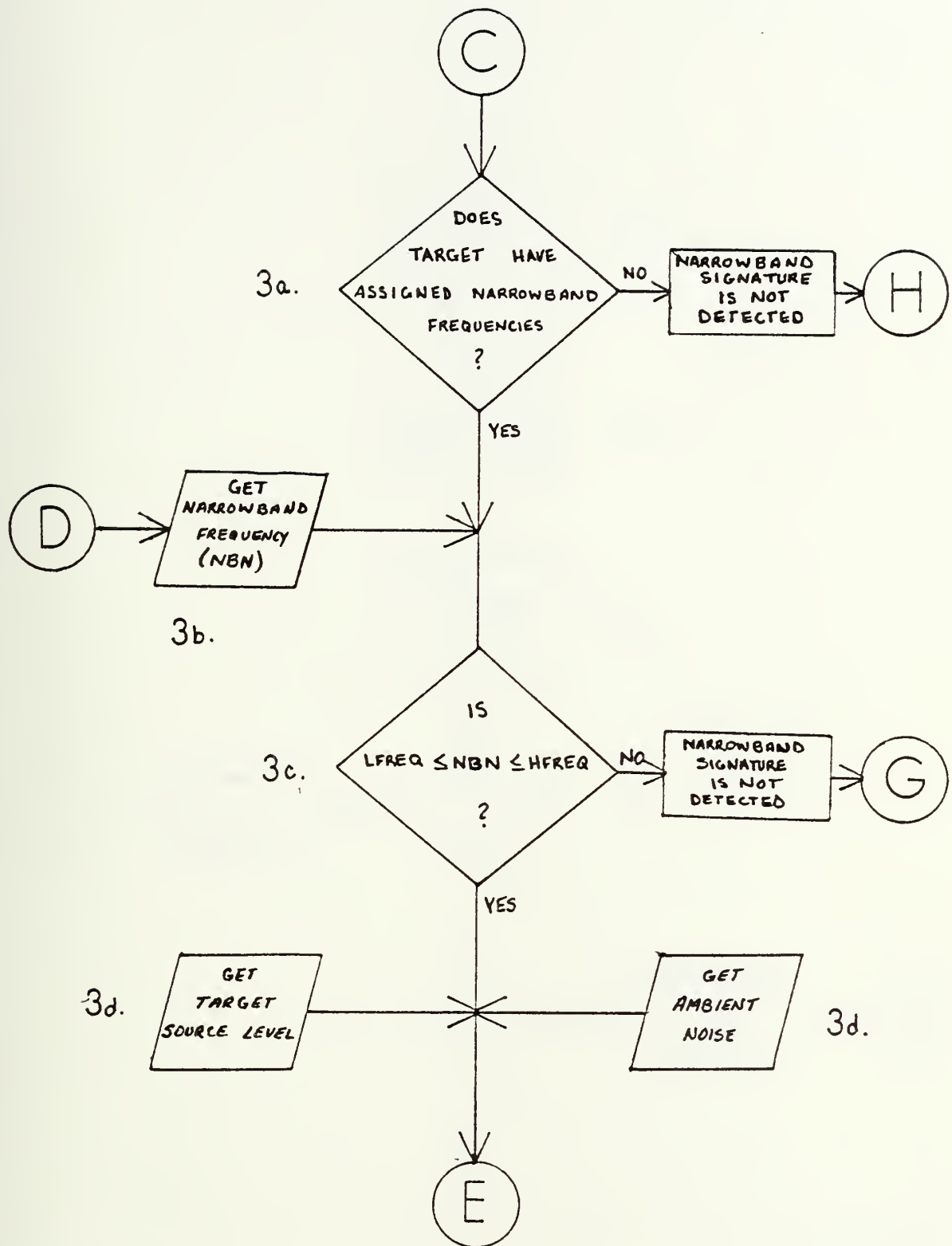


Figure 5-3. Steps 3a through 3d

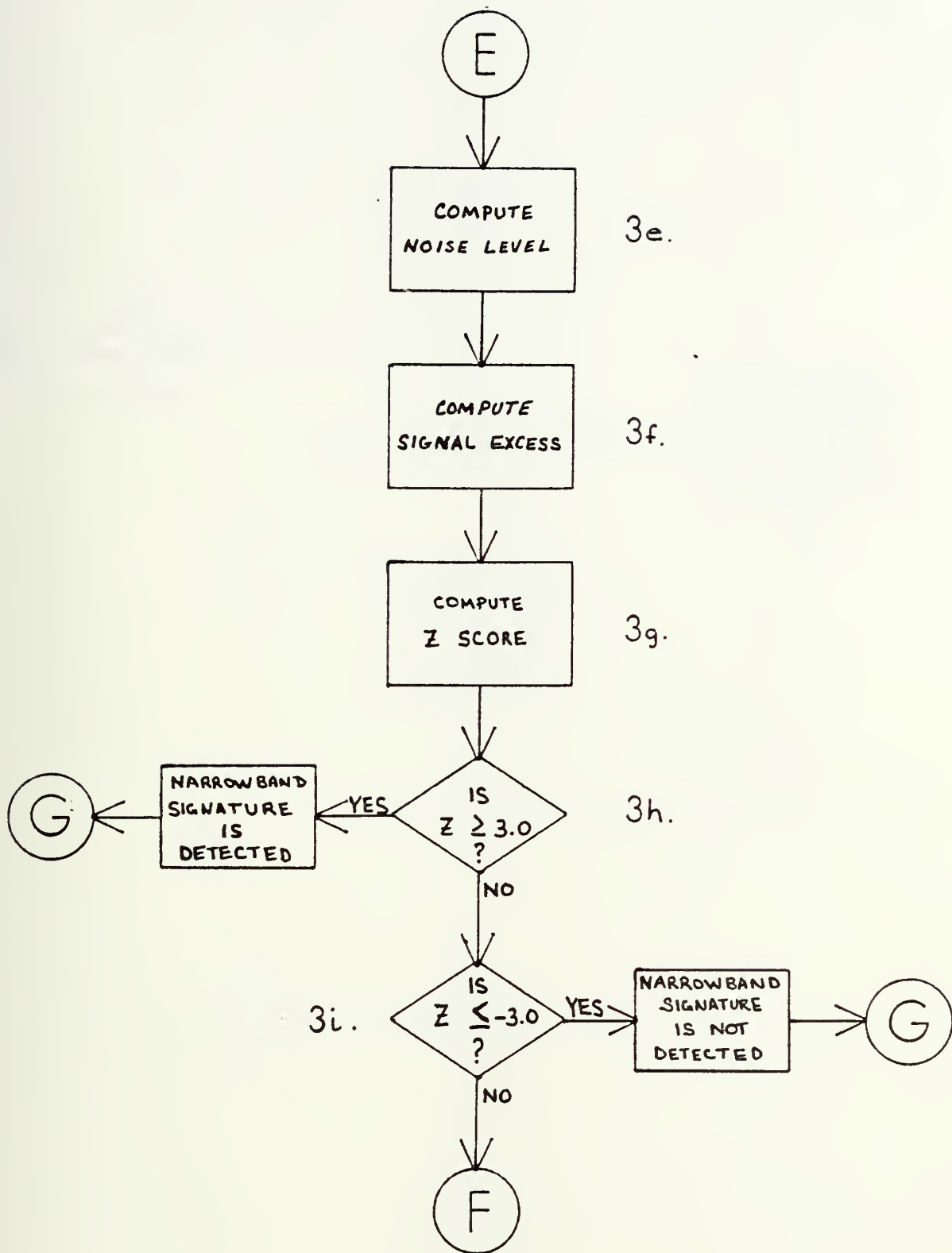


Figure 5-4. Steps 3e through 3i

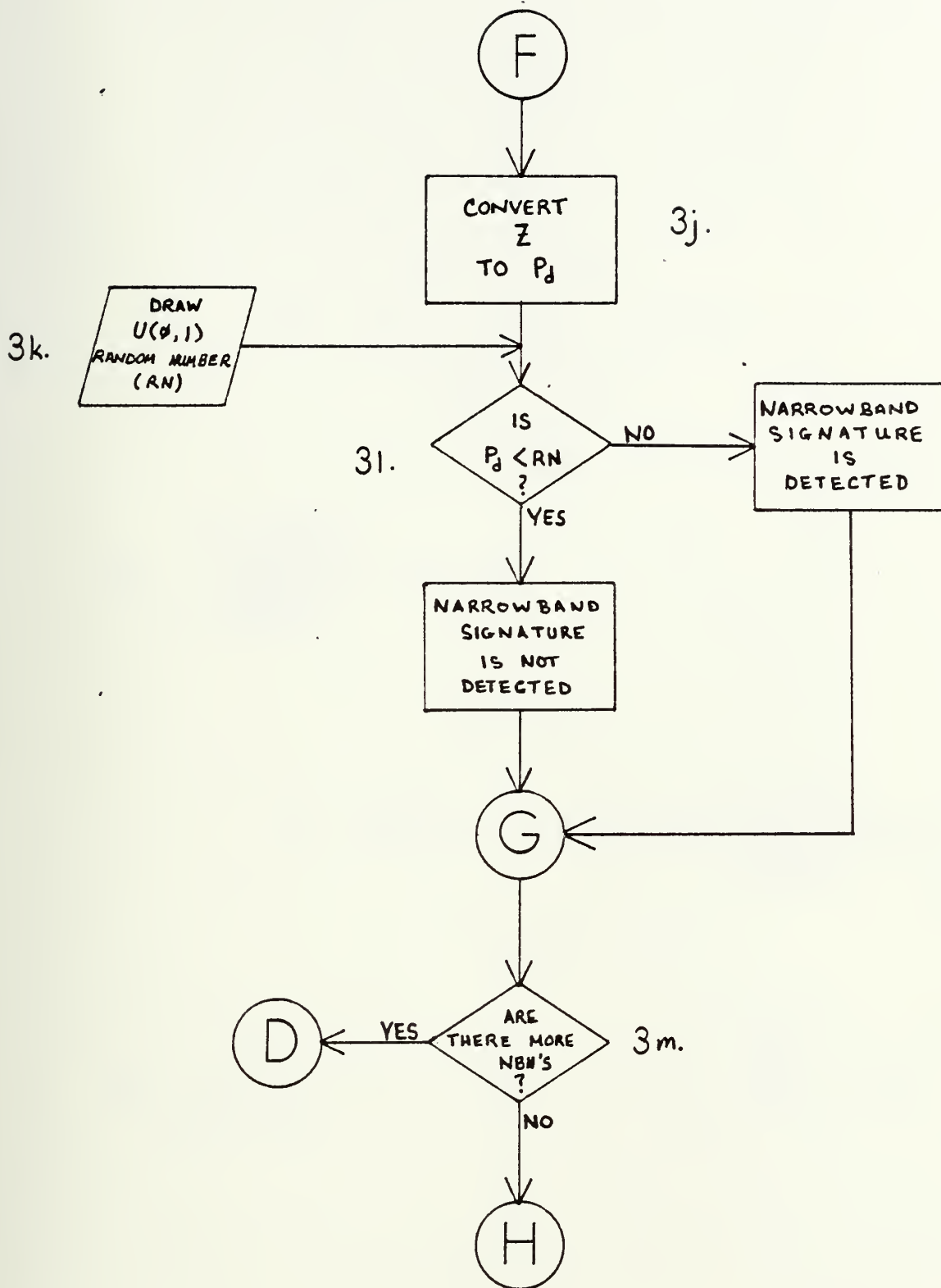


Figure 5-5. Steps 3j through 3m

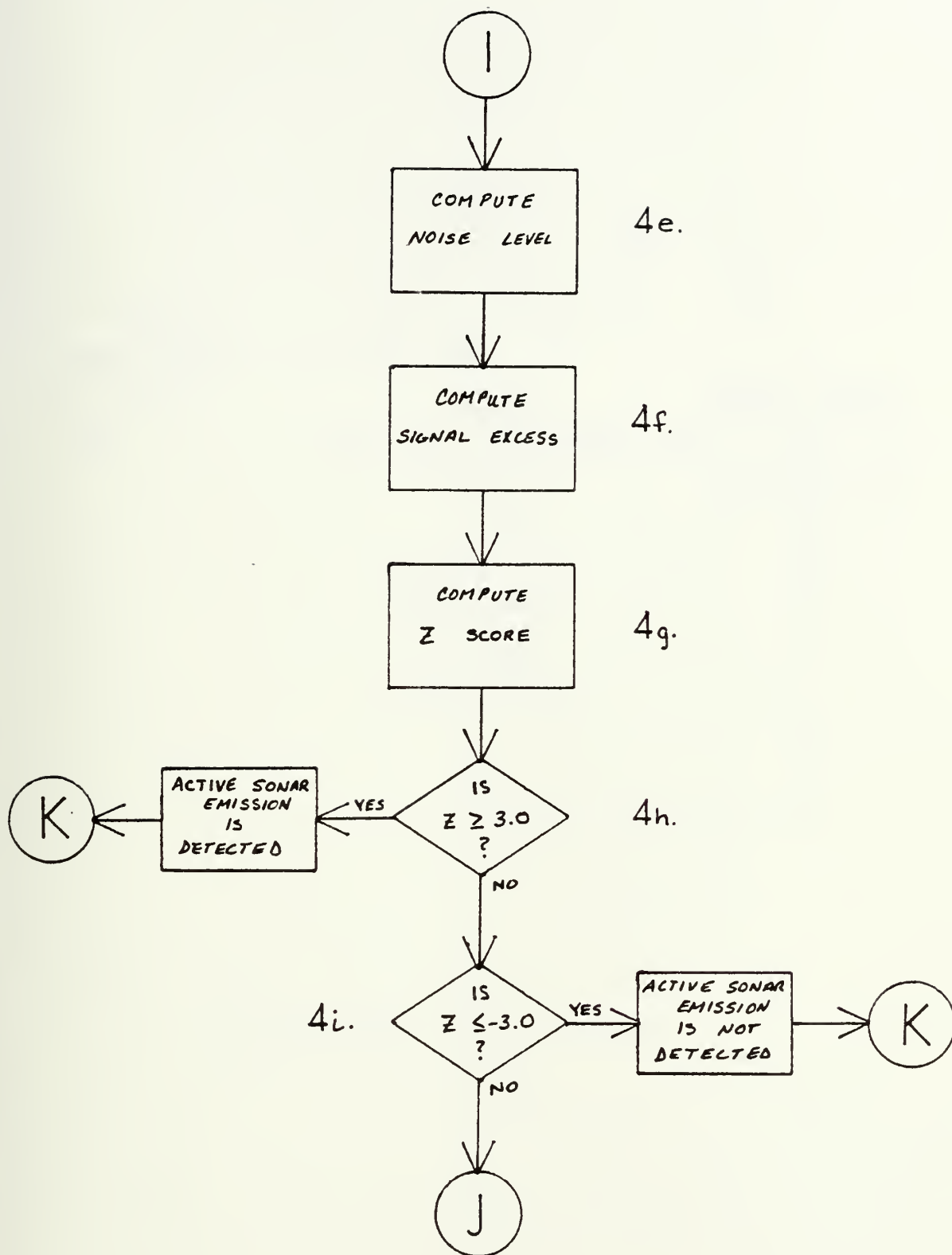


Figure 5-7. Steps 4e through 4i

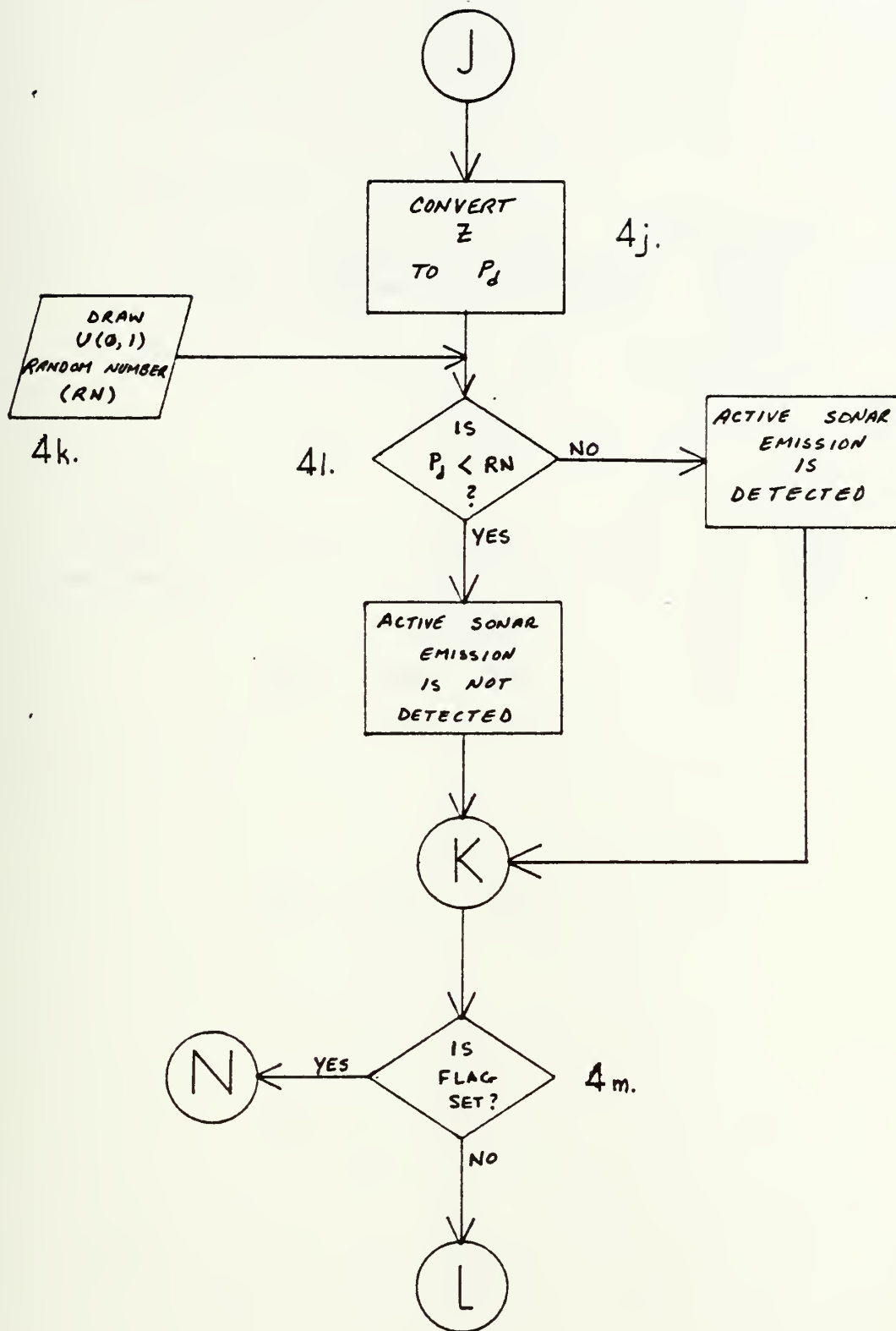


Figure 5-8. Steps 4j through 4m

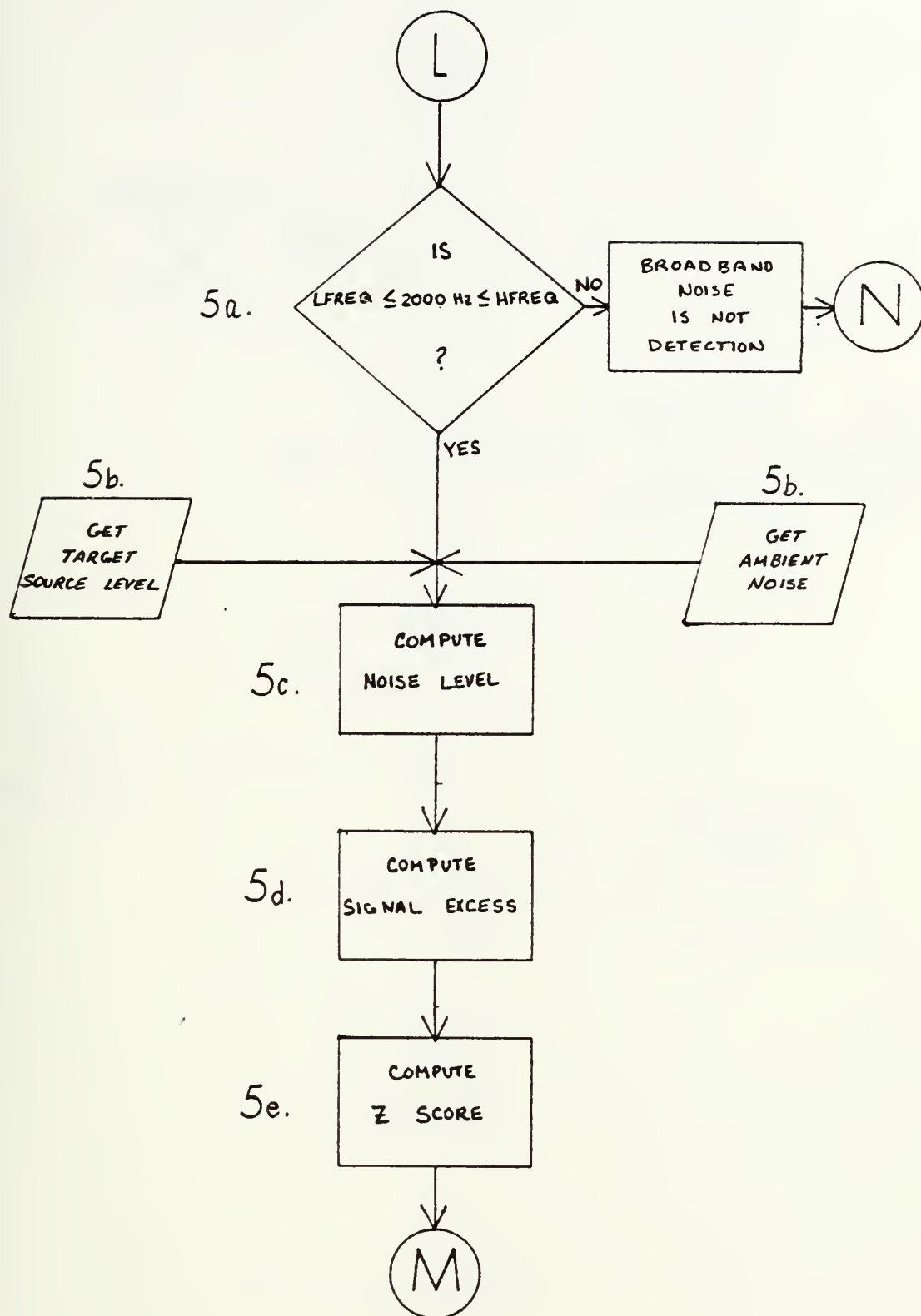


Figure 5-9. Steps 5a through 5e

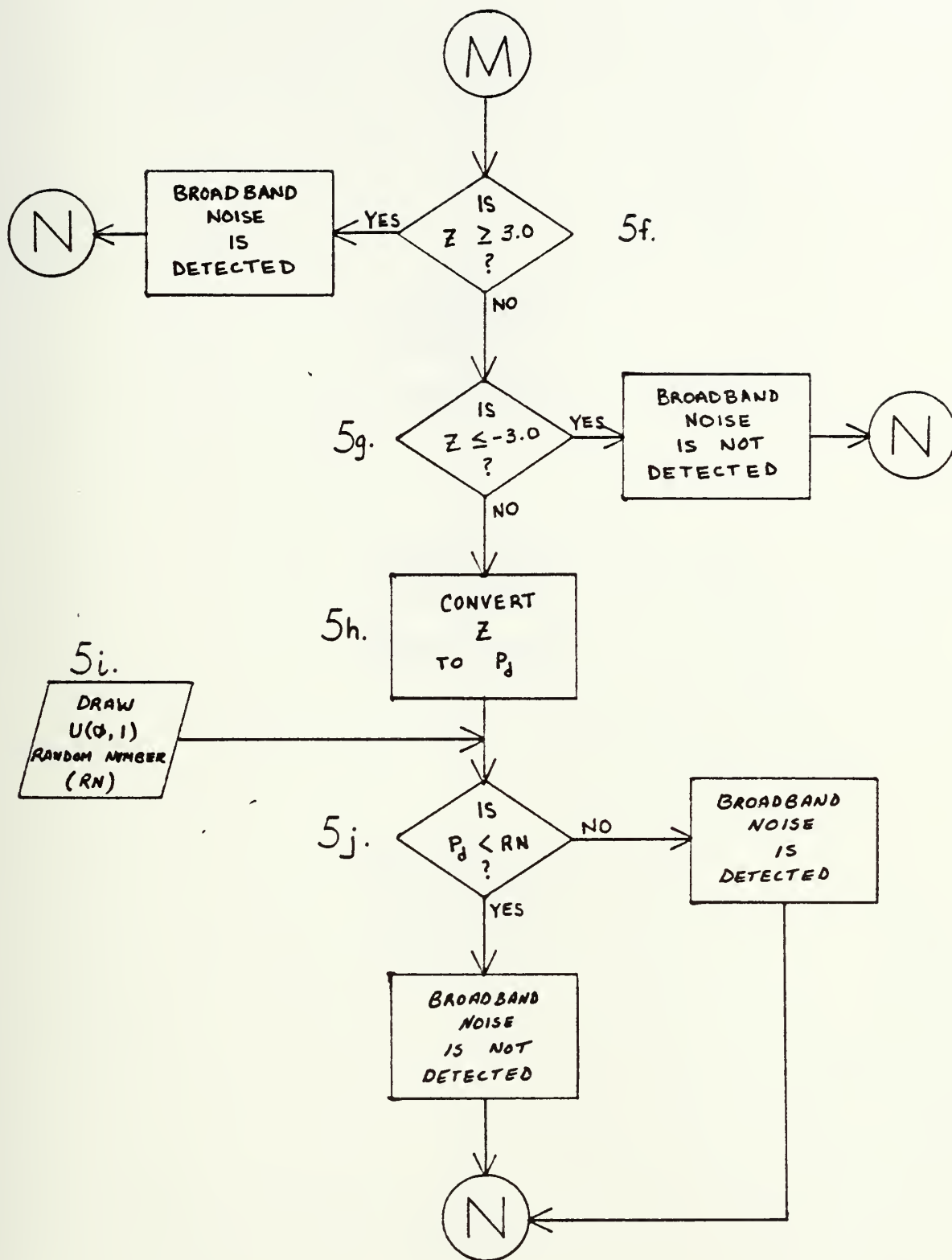


Figure 5-10. Steps 5f through 5j

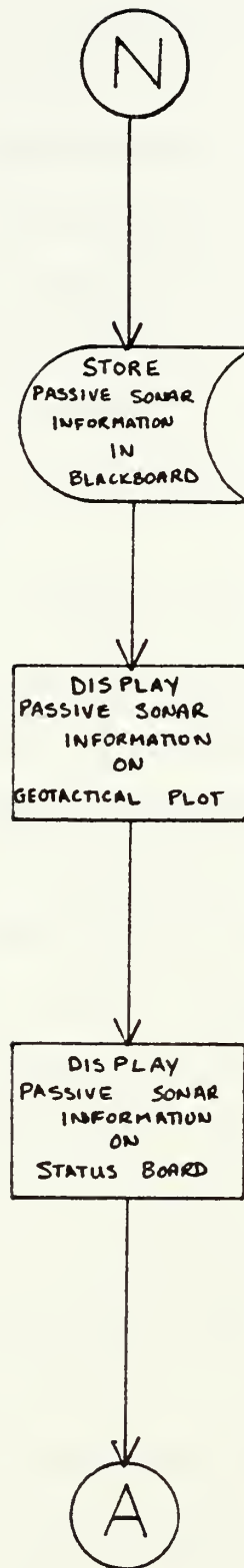


Figure 5-11. Step 6

three acoustic elements: narrowband signature, active sonar emission, or broadband noise. In the flow diagram, the questions, data, and computations pertaining to all three acoustic elements are considered first. The diagram then goes through a loop for each of the acoustic elements to determine whether there is passive contact in any one of the three elements. For the purpose of this explanation the sensor will be referred to as "blue" and the target will be referred to as "orange".

Since "blue" is the detector, the parameters of interest associated with "blue" are the characteristics of the passive sonar system used and those platform characteristics which directly affect sonar performance, for example ship's speed. The parameters associated with "orange" are the characteristics of the platform and the characteristics of the active sonar system used by "orange". All of the above platform and systems performance characteristics are in the appropriate BUILD database file. The remaining parameters are associated with the environment, or ocean medium. These parameters are found in the ENVIRONMENT file. So, the parameters required to determine passive detection can be put into three distinct groups, 1) those associated with the detecting platform; 2) those associated with the target, and 3) those associated with the medium.

The parameters in the passive sonar equation can likewise be separated into those associated with the sensor,

the target, and the medium. Associated with the sensor are recognition differential (RD), directivity index (DI), and detecting platform self noise (SN). Associated with the target is the target source level (SL). Associated with the medium are ambient noise (AN) and transmission loss (TL). These parameters are included in the appropriate database characteristic and environment files.

The following is a step-by-step explanation of the flow diagram.

STEP 1a:

Parameters associated with the sensor are retrieved from the database characteristic files in BUILD.

They are:

- 1) Sonar system low frequency limit (LFREQ)
- 2) Sonar system high frequency limit (HFREQ)
- 3) "Blue" self noise (SN)
(corresponding to "blue's" speed)
- 4) Sonar system recognition differential (RD)
- 5) Sonar system directivity index (DI)
(corresponding to target angle off the bow)
- 6) Sonar system vertical beamwidth (VERBW)
- 7) Sonar system horizontal beamwidth (HZBW)

STEP 1b:

Sonic layer depth (SLD) is retrieved from the ENVIRONMENT file.

SLD is used to compute the Sensor/Target layer geometry.

STEP 1c:

The following information is extracted from the blackboard:

- 1) Range from "blue" to "orange"
- 2) Angle off the bow
- 3) Vertical angle
- 4) Horizontal angle
- 5) Depth of both platforms
- 6) Speed of both platforms
- 7) Maximum sonar range

STEP 2a:

Check the range from "blue" to "orange".

If the range from "blue" to "orange" is greater than the maximum sonar range there is no passive sonar detection. Proceed to examine next target/sensor pair for passive sonar detection. (Maximum sonar range is a blackboard parameter typically set to 120 nautical miles by the operator during scenario preparation using FORCE or during the game.)

If the range is less than or equal to the maximum sonar range, the detection process continues.

STEP 2b:

Check vertical angle between the sensor and the target.

If the angle is greater than VERBW, there is no passive detection. Proceed to next target/sensor pair.

If the angle is less than or equal to VERBW, continue with Step 2c.

STEP 2c:

Check horizontal angle between the sensor and the target.

If the angle is greater than HZBW, set flag and proceed to Step 4a. (Note: The flag is set because NWISS allows active emissions to be detected even if the target is outside the horizontal beamwidth of the detecting platform.)

If the angle is less than or equal to HZBW, continue with Step 3a.

STEP 3a:

Determine if "orange" has any narrowband frequencies.

If "orange" has narrowband frequencies continue with Step 3b.

If "orange" has no narrowband frequencies proceed to Step 4a.

STEP 3b:

Retrieve "orange's" narrowband frequencies from the BUILD file. (Labeled NBN_).

STEP 3c:

Check if "orange's" narrowband frequency is greater than or equal to "blue's" low frequency limit and less than or equal to "blue's" high frequency limit (i.e., Is $LFREQ \leq NBN_ \leq HFREQ$?).

If NBN_ does lie between LFREQ and HFREQ inclusive, continue with Step 3d.

If NBN_ does not lie between LFREQ and HFREQ inclusive, passive sonar detection of the narrowband frequency is not possible. Proceed to Step 3m.

STEP 3d:

Retrieve "orange" target source level from BUILD file, ambient noise and transmission loss from ENVIRONMENT file.

STEP 3e:

Compute the noise level (NL).

Noise level is the power sum of "blue" self noise and ambient noise.

$$NL = 10 \log [10^{(AN/10)} + 10^{(SN/10)}]$$

STEP 3f:

Compute signal excess (SE).

$$SE = SL - NL - TL - RD + DI$$

STEP 3g:

Compute Z score.

$$Z = SE/2$$

STEP 3h:

Is Z greater than or equal to 3.0?

If $Z \geq 3.0$ passive sonar detection of the narrowband frequency is made (i.e., there is a 100% probability of detection). Proceed to step 3m.

If $Z < 3.0$ continue with Step 3i.

STEP 3i:

Is Z greater than or equal to -3.0?

If $Z \leq -3.0$ passive sonar detection of the narrowband frequency is not made (i.e., there is a 0% probability of detection). Proceed to Step 3m.

If $Z > -3.0$ (i.e., $-3.0 < Z < 3.0$) continue with Step 3j).

STEP 3j:

Convert Z score to a probability of detection (P_d) from a table of cumulative standard normal distribution.

STEP 3k:

Draw a random number (RN) from a uniform (0,1) distribution.

STEP 3l:

Compare the probability of detection to the random number.

If $P_d \geq RN$, passive detection of the narrowband frequency is made.

If $P_d < RN$, passive detection of the narrowband frequency is not made.

STEP 3m:

Check for more narrowband frequencies.

If there are more narrowband frequencies return to Step 3b.

If there are no more narrowband frequencies continue with Step 4a.

STEP 4a:

Check for active sonar emissions from "orange".

If "orange" is not using active sonar proceed to Step 5a.

If "orange" is using active sonar continue with Step 4b.

STEP 4b:

Retrieve "orange's" active sonar frequency and source level from the BUILD file. (Labeled CFREQ and LEVEL, respectively).

STEP 4c:

Check if active sonar center frequency is greater than or equal to "blue's" low frequency limit and less than or equal to "blue's" high frequency limit (i.e., Is $LFREQ \leq CFREQ \leq HFREQ$?).

If CFREQ does lie between LFREQ and HFREQ inclusive, continue with Step 4d.

If CFREQ does not lie between LFREQ AND HFREQ inclusive, passive sonar detection of the active sonar emission is not possible. Proceed to Step 5a.

STEP 4d:

Retrieve ambient noise and transmission loss from ENVIRONMENT file.

STEP 4e:

Compute the noise level (NL).

Noise level is the power sum of "blue" self noise and ambient noise.

$$NL = 10 \log [10^{(AN/10)} + 10^{(SN/10)}]$$

STEP 4f:

Compute signal excess (SE).

$$SE = SL - NL - TL - RD + DI$$

STEP 4g:

Compute Z score.

$$Z = SE/2$$

STEP 4h:

Is Z greater than or equal to 3.0?

If $Z \geq 3.0$ passive sonar detection of the active sonar emission is made (i.e., there is a 100% probability of detection). Proceed to Step 5a.

If $Z < 3.0$ continue with Step 4i.

STEP 4i:

Is Z less than or equal to -3.0?

If $Z \leq -3.0$ passive sonar detection of the active sonar emission is not made (i.e., there is a 0% probability of detection). Proceed to Step 5a.

If $Z > -3.0$ (i.e., $-3.0 < Z < 3.0$) continue with Step 4j.

STEP 4j:

Convert Z score to a probability of detection (P_d) from a table of cumulative standard normal distribution.

STEP 4k:

Draw a random number (RN) from a uniform (0,1) distribution.

STEP 4l:

Compare the probability of detection to the random number.

If $P_d \geq RN$, passive detection of the active sonar emission is made.

If $P_d < RN$, passive detection of the active sonar emission is not made.

STEP 4m:

Check for the flag set in Step 2c.

If flag is set proceed to Step 6a.

If flag is not set continue with Step 5a.

STEP 5a:

Check for broadband noise detection. Is 2000 Hz greater than or equal to "blue" low frequency limit and less than or equal to "blue" high frequency limit? (i.e., Is $LFREQ \leq 2000 \text{ Hz} \leq HFREQ$?)

If 2000 Hz lies between LFREQ and HFREQ inclusive, continue with Step 5b.

If 2000 Hz does not lie between LFREQ and HFREQ inclusive, passive sonar detection of broadband noise is not possible. Proceed to Step 6.

STEP 5b:

Retrieve "orange" target source level from BUILD file, ambient noise and transmission loss from ENVIRONMENT file.

STEP 5c:

Compute the noise level (NL).

Noise level is the power sum of "blue" self noise and ambient noise.

$$NL = 10 \log \left[\frac{AN}{10} + 10^{((SN-27)/10)} \right]$$

STEP 5d:

Compute signal excess (SE).

$$SE = (SL-27) - NL - TL - RD + DI$$

STEP 5e:

Compute Z score.

$$Z = SE/2$$

STEP 5f:

Is Z greater than or equal to 3.0?

If $Z \geq 3.0$ passive sonar detection broadband noise is made (i.e., there is a 100% probability of detection). Proceed to Step 6.

If $Z < 3.0$ continue with Step 5g.

STEP 5g:

Is Z less than or equal to -3.0?

If $Z \leq -3.0$ passive sonar detection of broadband noise is not made (i.e., there is a 0% probability of detection). Proceed to Step 6.

If $Z > -3.0$ (i.e., $-3.0 < Z < 3.0$) continue with Step 5h.

STEP 5h:

Convert Z score to a probability of detection (P_d) from a table of cumulative standard normal distribution.

STEP 5i:

Draw a random number (RN) from a uniform (0,1) distribution.

STEP 5J:

Compare the probability of detection to the random number.

If $P_d \geq RN$ passive detection of broadband noise is made.

If $P_d < RN$ passive detection of broadband noise is not made.

STEP 6:

Results of the passive detection process.

All of the information determined by the detection process is made available to the blackboard for retrieval by the status board and geotactical display programs. It is then displayed to the player on the appropriate status board and on the geotactical display.

TABLE 5-1

Passive Sonar Status Board

```

View: BLUE1          PASSIVE SONAR STATUS BOARD - Page 1          Game Time: 010444
                        ----- TMA -----
DET  TRACK  TIME  CLASS  SB BRG BB ECHO  RNG CRS SPD GUAL  -----LINE FREQ-----
-----
DD1  BP001  0219  POSSB      003 Y
      (ECHO2)      (000)
DD1  BP002  0324  POSSB      000 Y
      (ECHO2)      (000)

```

A sample passive status board is shown in Table 5-1.

The following is an explanation of what is displayed in each column:

- Column 1. DET: Displays the name of the detecting platform.
- Column 2. TRACK: Displays the track number of the contact. (On a control station status board the name of the contact is also displayed in parentheses below the track number).
- Column 3. TIME: Displays time of last detection.
- Column 4. CLASS: Displays classification of detection.
- Column 5. SB: Displays the number of the sonobuoy in contact if the detection is made by a sonobuoy.
- Column 6. BRG: Displays bearing to the contact with the bearing error applied. (On a control status board the actual bearing is also displayed in parentheses.)

Column 7. BB: Displays a Y if the contact is generated by a broadband noise detection.

Column 8. ECHO: Displays the center frequency of the active sonar if active sonar emissions are detected.

Columns 9 - 12. TMA: Displays target motion analysis information.

Columns 13 - 15. LINE FREQ: Displays narrowband frequencies if the target's narrowband signature was detected.

The geotactical display uses NTDS symbology to display platforms and bearing lines to contacts. Each bearing line is identified by the track number.

VI. DETERMINING FIGURE OF MERIT AND ITS APPLICATIONS TO NWISS

The figure of merit (FOM) is a measure of a particular sonar system's capability against a specific target in a distinct ocean area. In NWISS the FOM is governed by the following equation:

$$\text{FOM} = \text{SL} - \text{NL} - \text{RD} + \text{DI} \quad (6-1)$$

FOM is computed by assuming a target source level, noise level, recognition differential, and directivity index. By definition of the recognition differential, the figure of merit represents the allowable transmission loss for a 50 percent probability of detection (See Chapter III, Eq. 3-2).

In NWISS there are no assumptions made in the calculation of FOM since the values for the parameters in Equation 6-1 are tabled, or are computed from tabled data. To illustrate the calculation of FOM the following simple scenario is used. With the FOM computed, the applications discussed in Chapter I can be shown.

The scenarios involve a U.S. surface ship versus an enemy submarine in two different environmental areas. The first environment is a generic environment developed at IBGTT/CSF called KGOOD.ENV. The second environment, which has been given the fictitious name of A123D, uses actual

Fleet Numerical Oceanographic Center data generated for a specific ocean area. By using the two environment areas, a comparison can be made between the two results to show the applications of the passive sonar model and the figure of merit. The objective is to compute the figure of merit for the particular scenario, then compare it to the transmission loss data in the environment file to determine ranges of detection. Appendix A discusses the environment files as well as providing the environment files used in the scenarios.

A. SCENARIOS

A U.S. surface ship operating in a sonar region with environment KGOOD.ENV is in a passive sonar encounter with an enemy submarine. The ship is doing 12 kts. on a course of 360 degrees T. The submarine is doing 10 kts. on a course of 150 degrees T, and operating at a depth of 350 feet. The bearing from the ship to the submarine is 355 degrees T.

1. Identifying the Parameters

To begin we look at the database characteristic file of the ship, Figure 6-1. Because the ship is the detecting platform, the only parameter of interest is in the line labeled SONAR. The name of the passive sonar system is sought, in this case PSON1. The data contributing to FOM corresponding to the detecting platform can now be found in

CLASS	SSHIP					
CAT	SURF					
TYPE	FF					
VMAX	27					
XSECT	31					
HDG	GYRO					
SPD	PTLOG					
CLRNG	15					
DTRNG	21					
TRKS	75					
BBN	128	140	144	163	160	165
NAV	SRN12					
LCHRT	1					
RECRT	1					
WAVE	20					
LACOM	20					
LASEN	20					
LAWPN	30					
LAFLD	5					
LASPD	10					
LAAJR	10					
RBOC	2	48				
NBN	91	144				
DECM	YES					
BLIP	YES					
RDESM	SPS10	75				
RDESM	SPS40	90				
RDESM	WLR1	70				
RDESM	SLR12	50				
RDESM	SPG53	80				
RDESM	LN66	90				
RDESM	MK115	60				
RDESM	URD4	60				
SONAR	PSON1					
SONAR	ASON1					
COMMS	UHF	80				
COMMS	HF	80				
COMMS	VHF	100				
MISS	HRPON	4				
BUOY	SSQ53	SONO	300			
BUOY	SSQ47	SONO	200			
WEAP	SSPRO	SAM	8			
WEAP	G554	GUN	600			
WEAP	MK46A	TORP	20			
WEAP	ASROC	TORP	12			
WEAP	MK46	TORP	22			
AIR	SH2F	1				

Figure 6-1. Database Characteristic File of Surface Ship

the database characteristic file of the sonar PSON1, Figure 6-2. The parameters in Figure 6-2 used to compute FOM are RD, DI, BBN, and NBN. But first, the ability of the sonar system to detect the frequencies of interest must be determined. To do this, the parameters LFREQ and HFREQ are compared to the frequency of interest which identify the target in each of the acoustic elements.

The frequencies of interest are 2000 Hz for broadband noise detection, the narrowband frequencies of the target, and the center frequency of the active sonar employed by the target. The narrowband frequencies and the center frequency of the active sonar are found in the characteristic files of the submarine and the active sonar, Figures 6-3 and 6-4, respectively. From Figure 6-3, the narrowband frequencies of the submarine are 300 Hz and 585 Hz. From Figure 6-4, the center frequency of the active sonar is 3000 Hz.

Returning to Figure 6-2, we note that LFREQ and HFREQ are 300 Hz and 2500 Hz, respectively. Therefore, the detection of the broadband noise and the narrowband signature is possible, while the detection of active sonar emissions is not since CFREQ is outside the range of LFREQ and HFREQ. Now we can examine the other parameters in Figure 6-2, noting in Table 4-1 that the narrowband frequencies 300 Hz and 585 Hz correspond to lines NBN11 and NBN12, respectively.

NAME	PSDN1					
CAT	PHULL					
CFREQ	2000					
LFREQ	300					
HFREQ	2500					
HZBW	8					
VERBW	45					
BRERR	2					
RD	-12					
DI00	21	21	21	21	21	21
DI60	21	21	21	21	21	21
DI120	21	21	21	10	0	-10
BBN	64	65	69	79	84	84
NBN1	300	300	300	300	300	300
NBN2	300	300	300	300	300	300
NBN3	300	300	300	300	300	300
NBN4	300	300	300	300	300	300
NBN5	300	300	300	300	300	300
NBN6	300	300	300	300	300	300
NBN7	300	300	300	300	300	300
NBN8	300	300	300	300	300	300
NBN9	300	300	300	300	300	300
NBN10	300	300	300	300	300	300
NBN11	73	77	77	80	82	300
NBN12	56	62	63	67	67	300
NBN13	46	53	54	59	62	300
NBN14	41	45	45	51	57	300
NBN15	39	41	43	51	57	300
NBN16	37	38	42	52	57	300
NBN17	36	37	41	51	57	300
NBN18	300	300	300	300	300	300
NBN19	300	300	300	300	300	300
NBN20	300	300	300	300	300	300

Figure 6-2. Database Characteristic File of Passive Sonar System

CLASS	SSUB					
CAT	NSUB					
TYPE	SSGN					
VMAX	22					
XSECT	22					
HDG	GYPG					
SPD	PTLOG					
CLRNG	6					
DTRNG	10					
TRKS	75					
BBN	137	139	141	143	145	147
DRATE	250					
KEEL	30					
PSCOP	60					
DR	SINS					
OMEGA	LWSPT					
NBN	300	145				
NBN	585	139				
RDESM	SNPTR	20				
RDESM	BRKSP	60				
SONAR	PSO2					
SONAR	ASON2					
COMMS	HF	90				
COMMS	UHF	90				
MISS	SSN7	8				
NAV	NAVST					
TORP	ET80	32				
WIRES	3					

Figure 6-3. Database Characteristic File of a Submarine

>NAME	ASON2
>CAT	AHULL
>CFREQ	3000
>LEVEL	240
MNFAL	4320
MNRPR	1440
MODE	DP
MODE	CZ

Figure 6-4. Database Characteristic File of Active Sonar System

The first parameter of interest is RD, it has a value of -12. To determine DI, note that the submarine is within 10 degrees of the bow of the ship, so we look at the first entry in line DI00. DI has a value of 21. Next, locate the values of self noise, both for the broadband case and the narrowband case. Since the ship is at 12 kts. the value of SN will be in the 10 kts. column, the second one from the left. In line BBN, that value is 65 dB. In lines NBN11 and NBN12 the values are 77 dB and 62 dB, respectively.

Figure 6-3 provides the parameters associated with the submarine. In this case there is only the target source level to determine. Since the submarine is doing 10 kts., the second column in the BBN line and the two NBN lines will provide the values for SL. In the broadband detection case SL is equal to 139 dB. In the narrowband detection case there is an SL for each frequency of interest. SL for the 300 Hz frequency is 145 dB, and for the 585 Hz frequency SL equals 139 dB.

Finally, the one parameter left to consider is the ambient noise. There is a separate ambient noise value for each of the frequencies of interest. This value for AN is drawn from the environment file KGOOD.ENV. In the broadband detection case the value of AN is read directly below the 2000 Hz in the ambient noise line. For this scenario AN

equals 57 dB for the broadband detection case. The AN for the 300 Hz frequency is read beneath 315 Hz in the ambient noise line and for the 585 Hz frequency under 630 Hz. For the 300 Hz case, AN equals 67 dB, and for the 585 Hz case, AN equals 65 dB. Table 6-1 is provided in summary.

TABLE 6-1
Summary of Detection Process

DETECTING PLATFORM	TARGET
RD = -12 DB	Broadband noise:
DI = 21 dB	SL = 139 dB
Broadband noise:	Narrowband signature:
SN = 65 dB	SL = 145 dB (300 Hz)
	SL = 139 dB (585 Hz)
Narrowband signature:	
SN = 77 dB (300 Hz)	
SN = 62 dB (585 Hz)	
ENVIRONMENT KGOOD	ENVIRONMENT A123D
Sonic Layer Depth=164 Ft	Sonic Layer Depth=314 Ft
Broadband noise:	Broadband noise:
AN = 57 dB	AN = 87 dB
Narrowband signature:	Narrowband signature:
AN = 67 dB (300 Hz)	AN = 85 dB (300 Hz)
AN = 65 dB (585 Hz)	AN = 86 dB (585 Hz)

2. Calculating FOM

The figure of merit is calculated using Equation 6-1. The variables SL, RD, and DI are in Table 6-1. NL

must be computed using Equation 4-2 for the narrowband case and Equation 4-5 for the broadband case. Equation 4-2 yields a NL of 77.4 for the 300 Hz narrowband signature detection case. Equation 4-2 yields a NL of 66.8 for the 585 Hz narrowband signature detection case. Equation 4-5 yields a NL of 57.1 for the broadband detection case.

There are three FOM's associated with this scenario, one for the broadband noise detection case and one for each of the two narrowband frequency cases. The following are the results of calculating FOM for each of the three cases:

Broadband noise:

$$\text{FOM} = 139 - 57.1 - (-12) + 21$$

$$\text{FOM} = 87.9 \text{ dB}$$

300 Hz narrowband signature:

$$\text{FOM} = 145 - 77.4 - (-12) + 21$$

$$\text{FOM} = 100.6 \text{ dB}$$

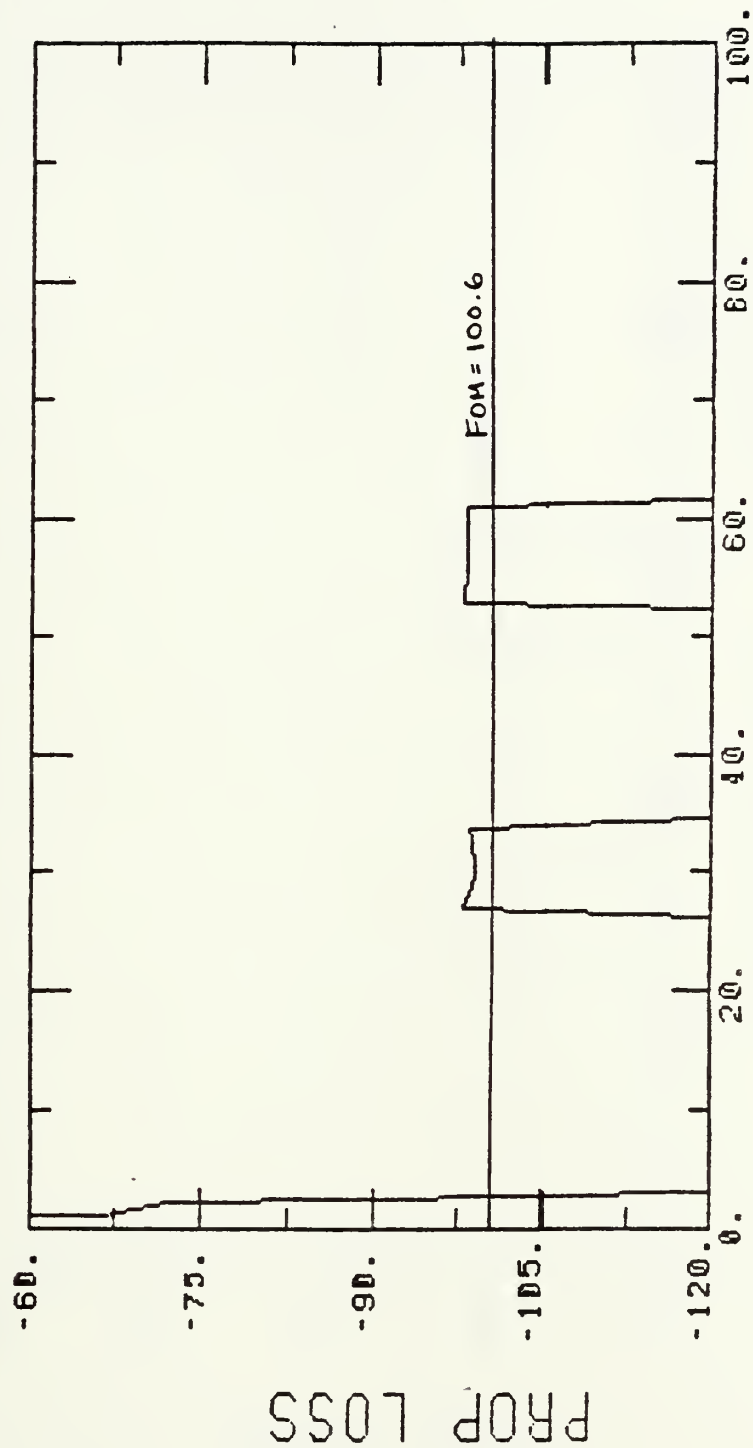
585 Hz narrowband signature:

$$\text{FOM} = 139 - 66.8 - (-12) + 21$$

$$\text{FOM} = 105.2$$

Figures 6-5, 6-6, and 6-7 show the computed FOM plotted on transmission loss curves for the respective frequencies of interest and source/receiver layer

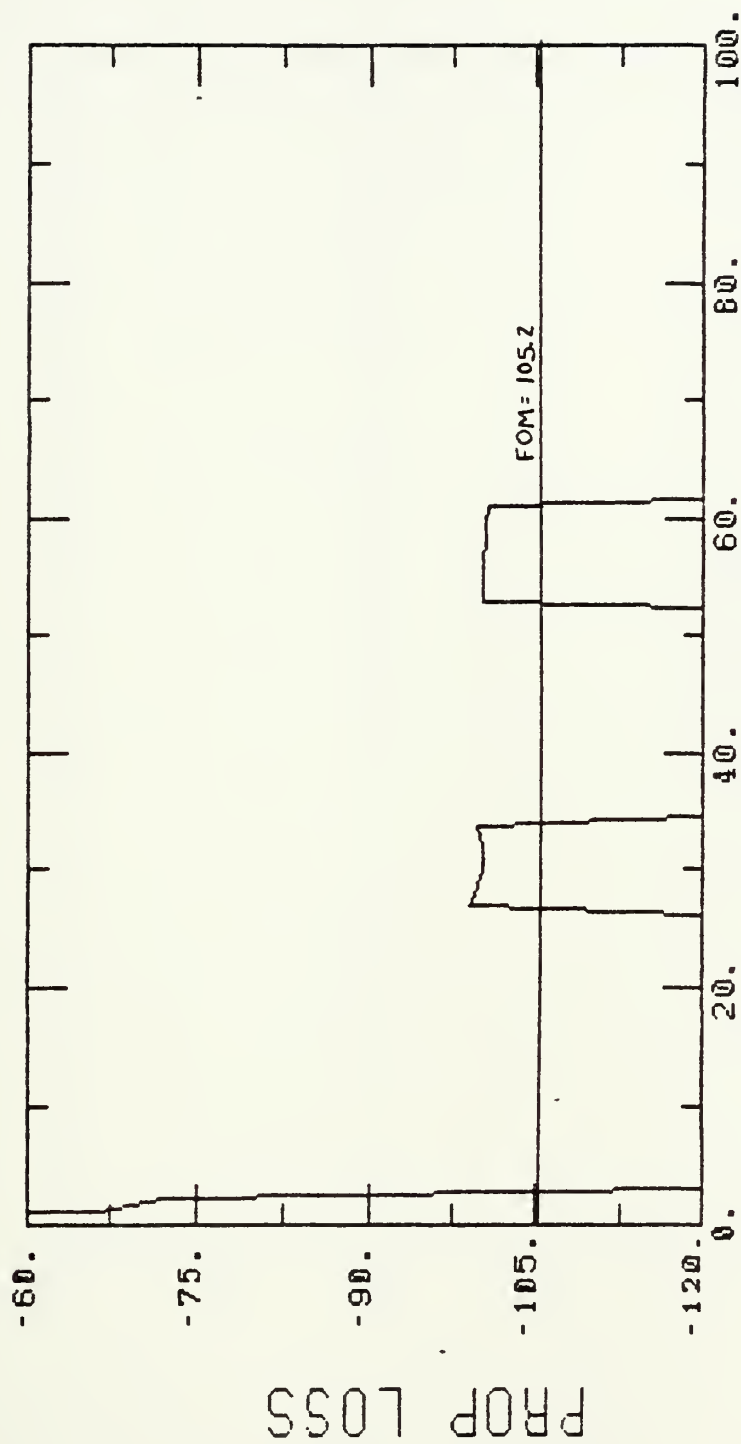
C315



KGOOD.ENV - RANGE

Figure 6-5. FOM vs. TL, 300 Hz, KGOOD Environment

C630



KGOOD.ENV - RANGE

Figure 6-6. FOM vs TL, 585 Hz, KGOOD Environment

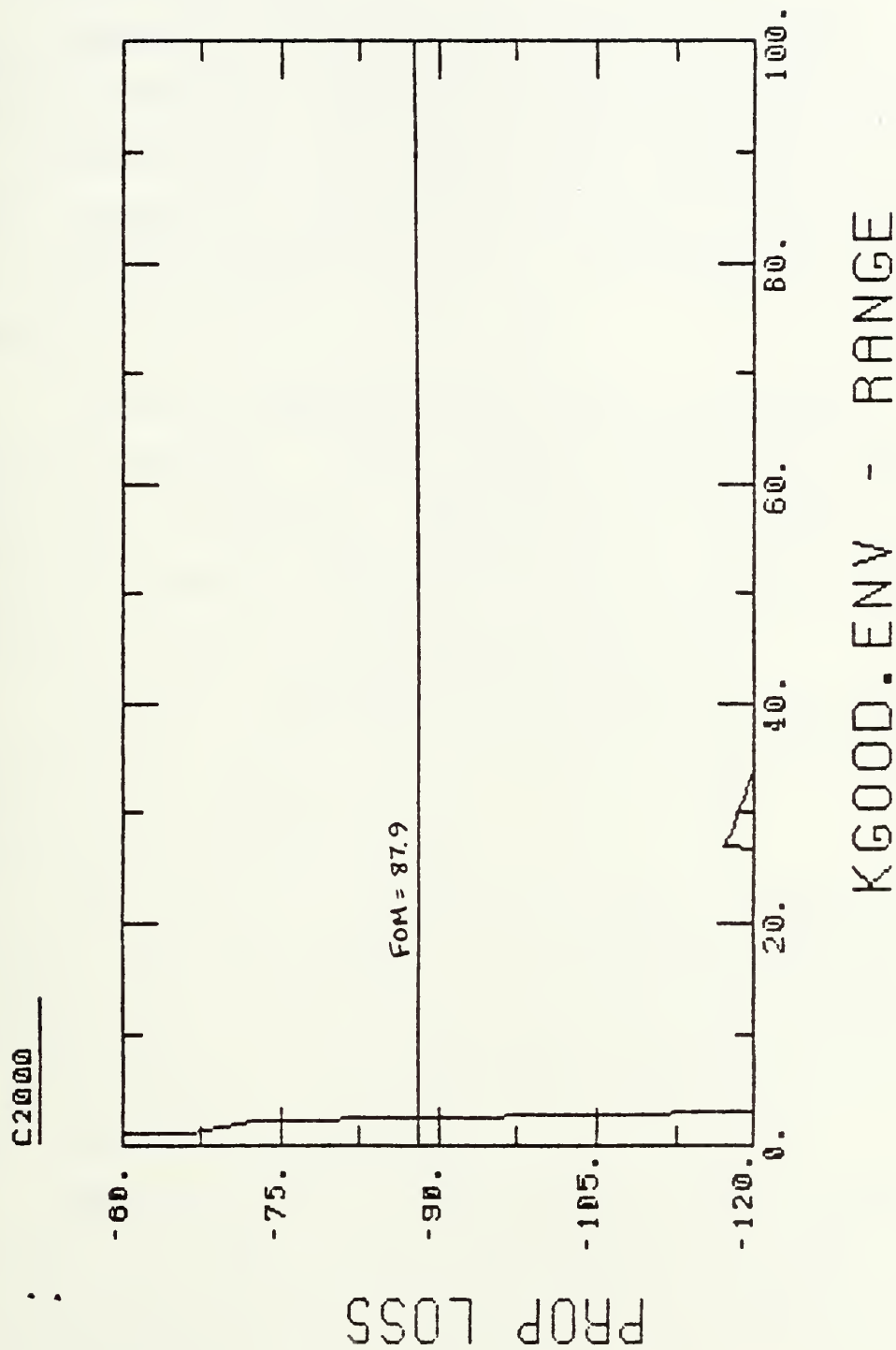


Figure 6-7. FOM vs. TL, Broadband Noise, KGOOD Environment

geometries. From each graph, the 50 percent probability of detection is read where the FOM line intersects the transmission loss curve.

Figure 6-5 represents the 300 Hz narrowband signature detection. The plotted FOM yields direct path and two convergence zone (CZ) passive sonar capability. The 50 percent probability of detection ranges are 4 NM for direct path, 28 NM to 33 NM for first CZ, and 54 NM to 61 NM for second CZ.

Figure 6-6 represents the 585 Hz narrowband signature detection. It also shows a direct path and two CZ passive sonar capability. The 50 percent probability of detection ranges are 3 NM for direct path, 28 NM to 33 NM for first CZ, and 53 to 61 NM for second CZ.

Figure 6-7 represents the broadband noise detection. The plotted FOM yields only a 3 NM direct path 50 percent probability of detection range.

The results of the expected ranges of detections above are reasonable because the environment KGOOD was modified to give those results. In using an environment file representing an actual ASW zone such as A123D, the results may not be so pleasing.

The FOM's for the case using environment A123D are computed in the same manner as previously discussed. The difference being the sonic layer depth, the ambient noise,

and the transmission loss curves used. The data corresponding to environment A123D is shown in Table 6-1. The computed FOM's are shown below.

Broadband noise:

$$\text{FOM} = 139 - 87.0 - (-12) + 21$$

$$\text{FOM} = 85.0 \text{ dB}$$

300 Hz narrowband signature:

$$\text{FOM} = 145 - 85.6 - (-12) + 21$$

$$\text{FOM} = 92.4 \text{ dB}$$

585 Hz narrowband signature:

$$\text{FOM} = 139 - 87.0 - (-12) + 21$$

$$\text{FOM} = 85 \text{ dB}$$

Figures 6-8, 6-9, and 6-10 are examples of using the transmission loss curves of environment A123D. The three figures show that only direct path detection will be observed. Note that for the 300 Hz narrowband detection, the 50 percent probability of detection range is 38 NM, while for the 585 Hz narrowband and the broadband detections, the 50 percent probability of detection ranges are 10 NM and 8 NM, respectively.

The 300 Hz narrowband detection results in an example of obtaining unreasonable detection ranges for the

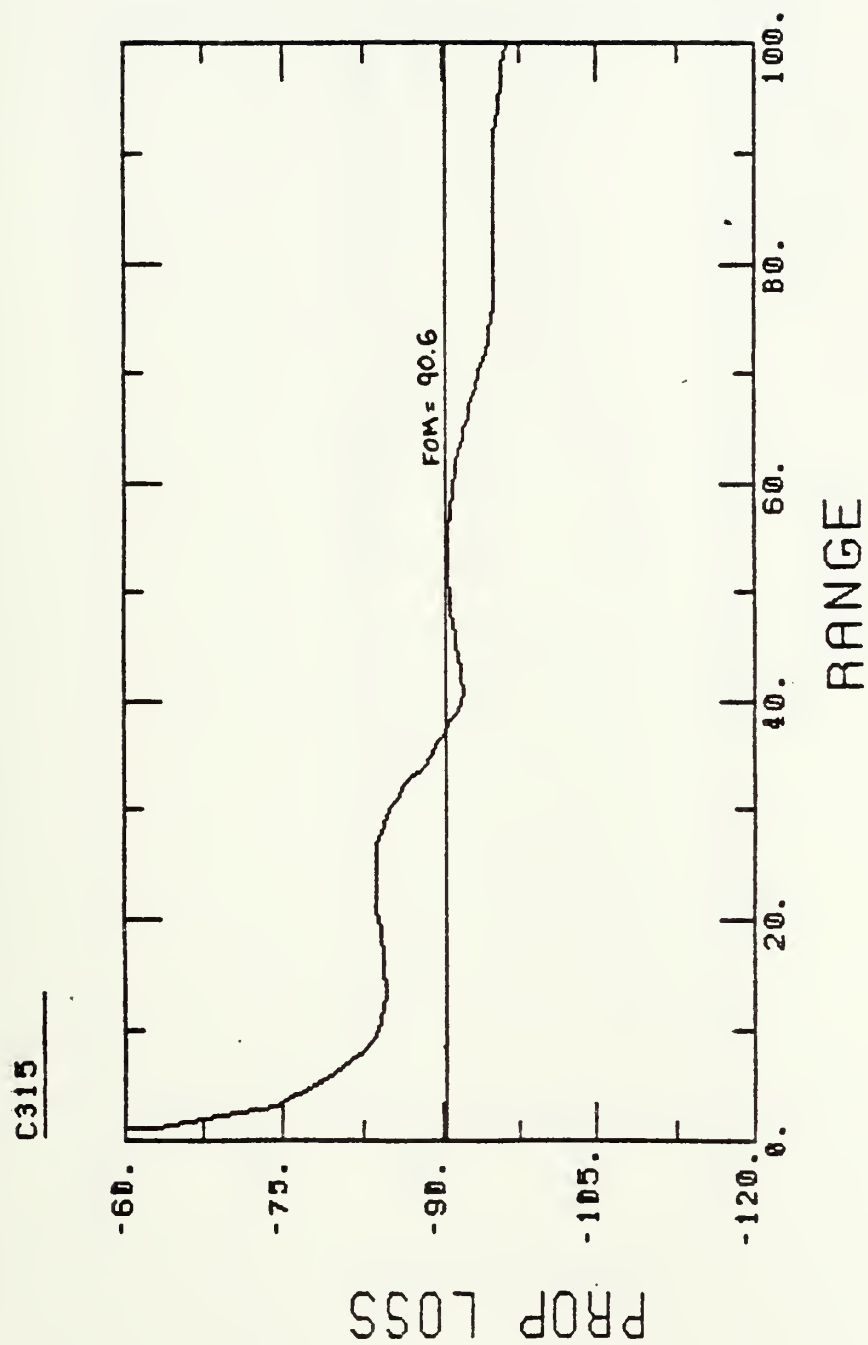


Figure 6-8. FOM vs. TL, 300 Hz, AL23D Environment

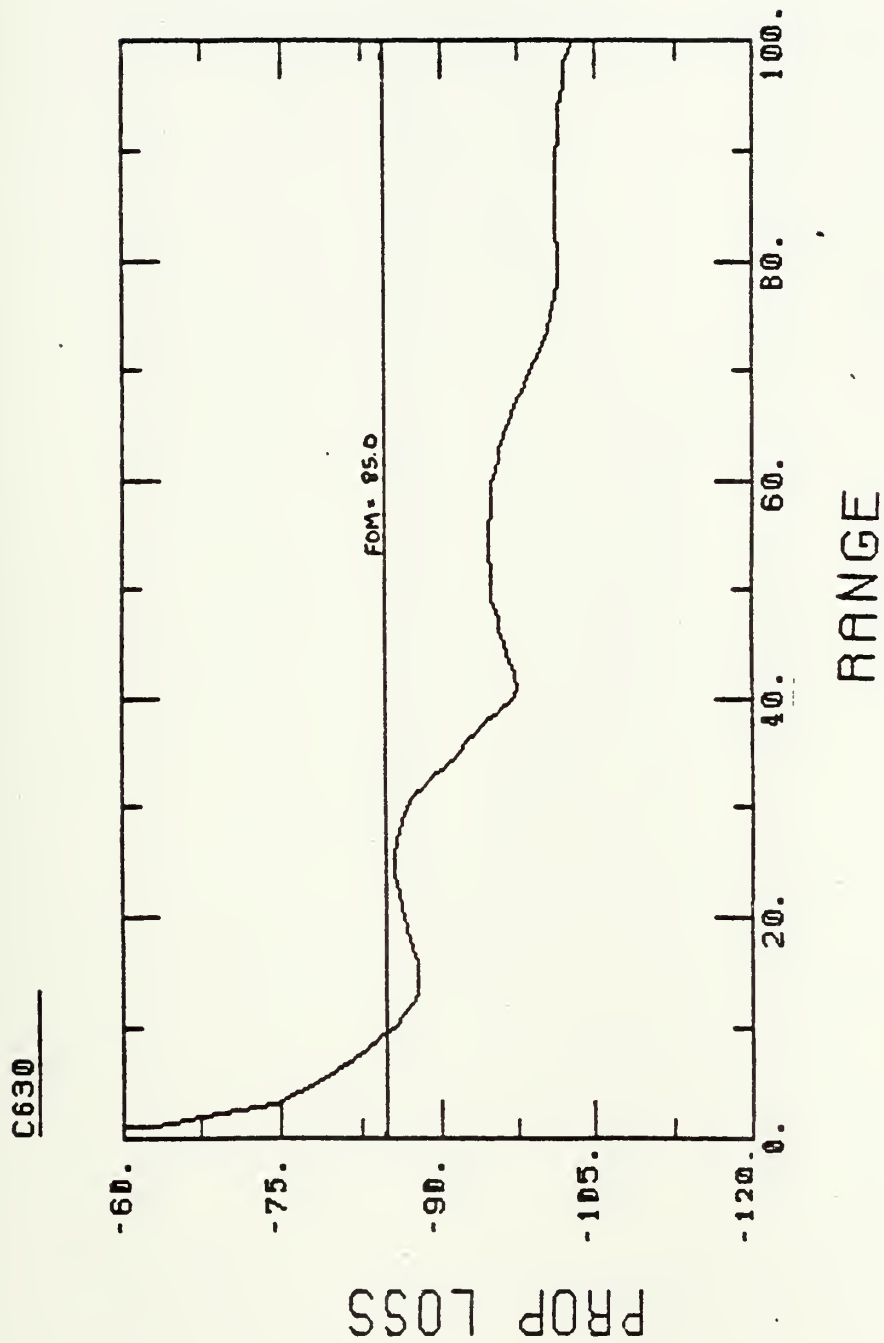


Figure 6-9. FOM vs. TL, 585 Hz, A123D Environment

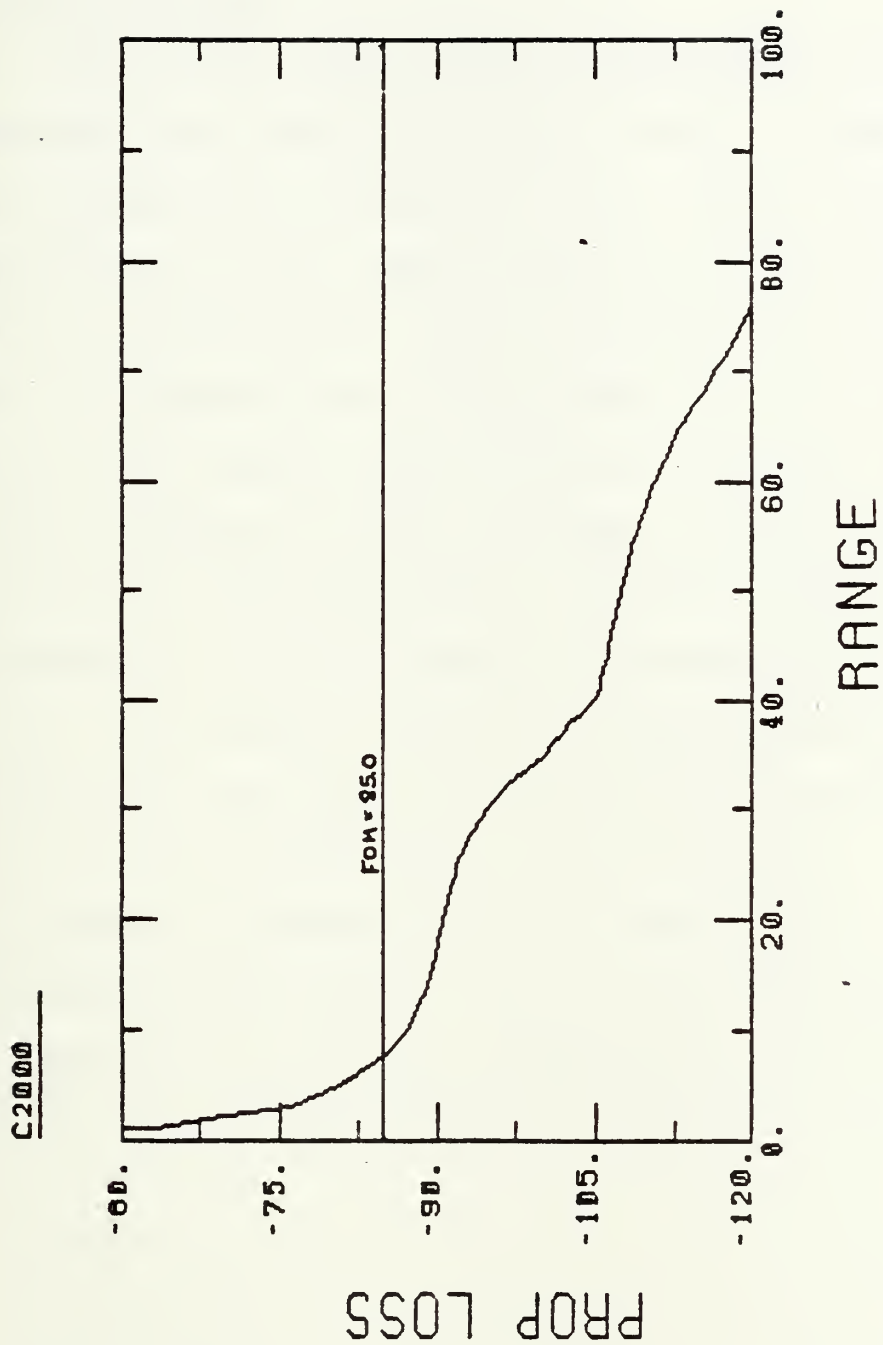


Figure 6-10. FOM vs. TL, Broadband Noise, Al23D Environment

purpose of tactical training. The operator can remedy the situation by adjusting the parameters to yield an FOM which will result in a desired 50 percent probability of detection range of detection.

For example, plot the desired range on the transmission loss curve as in Figure 6-11. A desired 50 percent probability of detection range of 5 NM yields a required FOM of 78 dB. Now the operator can determine which parameter in Equation 6-1 can be changed most readily to produce the desired FOM. In this case, the best choice is a parameter that affects only the 300 Hz narrowband signature detection, because the other two cases are satisfactory. The previously calculated FOM for the 300 Hz case was 92.4 dB, therefore, a -14.4 dB change is required to yield an FOM of 78 dB. This change can best be accomplished by modifying the noise level (NL) term. The previous NL was 85.6, and by adding 14.4 the desired results can be obtained. The NL is 100 dB and can be computed using an ambient noise of 100 dB. So, by changing the ambient noise in the environment file A123D from 85 dB to 100 dB, the operator is able to produce a desired 50 percent probability of detection range.

C315

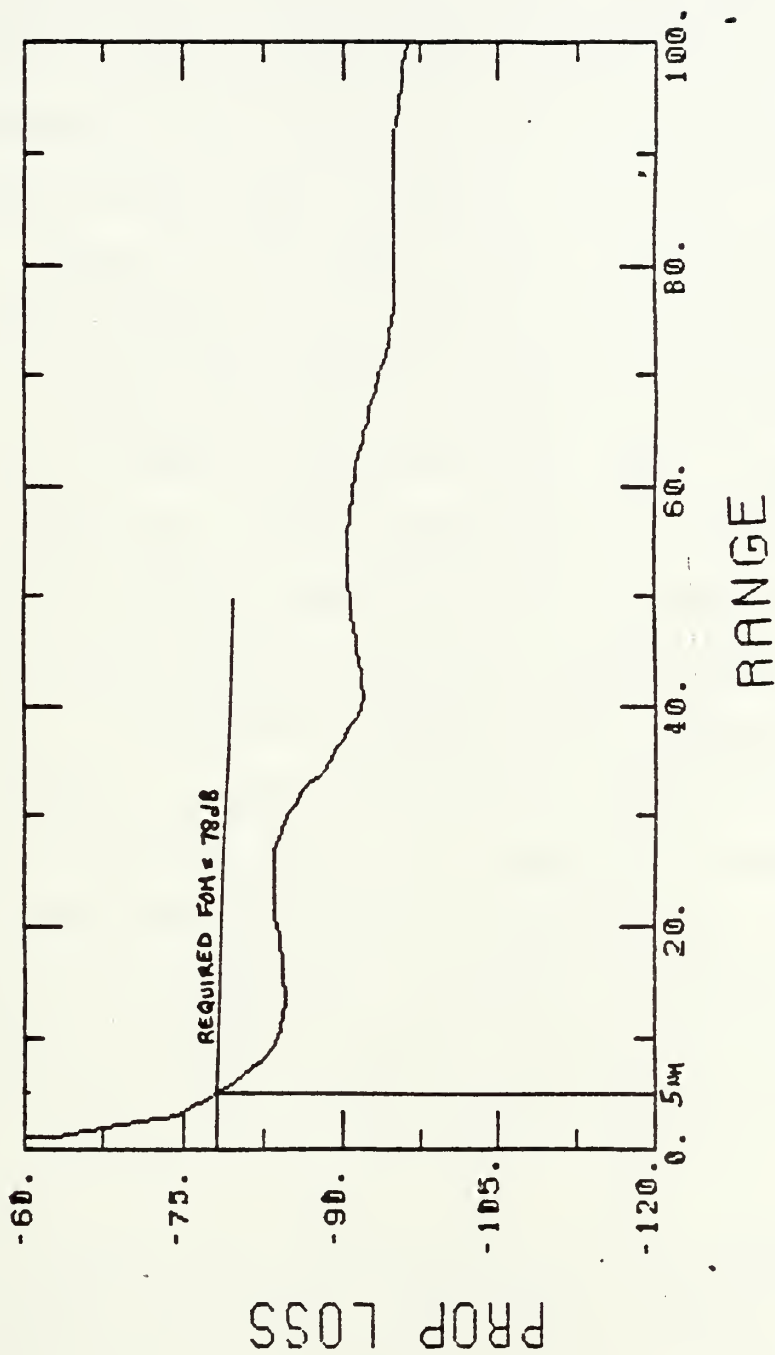


Figure 6-11. Required FOM for Desired Range of 5 NM

VII. CONCLUSIONS AND RECOMMENDATIONS

The objectives of this thesis were to document the passive sonar model in NWISS and to show its applications. In accomplishing these objectives it can be seen that the passive sonar model adds to NWISS's value as a tactical trainer. However, as discussed and as will be shown, the passive sonar model may lack the validity necessary to make it useful in the developmental research or analysis.

The way in which the passive sonar model is organized makes it useful as a tactics training aid. The equation used to compute signal excess is fairly simple, and the parameters in that equation are all readily accessible to the operator. This makes it possible for the operator to create a scenario to meet the training requirements. If the training requirements change, for instance, shorter detection ranges are desired, the operator can simply make adjustments to the database to reflect the changes. While this flexibility makes the passive sonar model valuable in a tactical training role, it also makes it difficult to validate.

It is primarily the organization of the database which makes validation difficult. The method of putting characteristic data into tables or lists, simplifies a

highly complex set of equations needed to model "real world" conditions. As examples, consider the values for directivity index, ambient noise, and narrowband target source level. The passive sonar model in NWISS uses a value for directivity index that is only a function of the bearing to the contact. In reality, the directivity index also depends on the frequency being detected. Ambient noise as listed in the environment file is only a function of frequency, but is also dependent on shipping density, weather, distance from shore, biologics, depth, and direction. The target source level used for narrowband frequency detection is not only a function of frequency but also a function of the speed of the target.

In conclusion, the passive sonar model adds to the value of NWISS as a tactical trainer, but in its present form, is limited in the use for developmental research or analysis. The continued use of the passive sonar model in NWISS for battle group tactical training provides a valuable asset for the fleet. The use of the passive sonar model for purposes of developmental research or analysis should be limited and any results should be carefully scrutinized.

The use of this thesis is recommended for anyone involved with the Naval Warfare Interactive Simulation System. It should be used to become familiar with the passive sonar model in order to prepare an ASW scenario, and

also to receive greater benefit from the training accomplished by NWISS. This thesis may also be used as a reference manual, and as an example to write reference manuals for the other models used in NWISS.

The applications of the passive sonar model to determine ranges of detection bring the following recommendations. With respect to the operator who is preparing a scenario, the use of figure of merit to determine range of detection gives an accurate representation of the capabilities of the sonar system modeled. Keeping the training requirements in mind, for example the ranges of detection desired, the operator can use the method described in Chapter VI to prepare the scenario to meet the training requirements. The player can similarly use the method described in Chapter VI to determine the expected ranges of detection and plan optimal tactics.

The applications of the passive sonar model described in Chapter VI is effective when used in simple scenarios such as one or two sensors versus one or two targets. For a more complex scenario such as a battle group training scenario, it is highly recommended that computer software be developed to accomplish the results of the applications described in Chapter VI.

APPENDIX A
NWISS ENVIRONMENT FILES

The purpose of this appendix is to familiarize the reader with how NWISS uses the environmental files. The addition of this appendix is due to the importance of the environment to passive sonar detection. The items discussed include: the creation of environment files, the review of environment files, the use of the environment files, and defining of sonar regions.

A. CREATION OF ENVIRONMENT FILES

In order to compile a set of usable environment files, the services of the Fleet Numerical Oceanographic Center (FNOC) in Monterey, California were solicited. It was desired that NWISS have the capability to offer the user a choice of environmental data corresponding to the area of operation, such as the ASW environmental zones for which FNOC provides prediction data. A request for the data necessary to create files for 42 ASW zones was sent to FNOC. The data for each zone was to be based on climatology for four months of the year, March, June, September, and December, so that 168 files would be created. The data for each zone provided by FNOC was edited, merged into a single source file, then processed by local programs at NOSC to generate an environment file compatible to NWISS.

The resulting environment files were named according to the ASW zone and the month of the data provided. The first four characters of the filename indicate the ASW zone, while the fifth letter of the filename represents the month that the data applies to, i.e., M=March, J=June, S=September and D=December. The filetypes used include ENV, TAB, and TXT. Filetype ENV is used for the version of the file formatted for use by the computer during the game. This version is not readable. The TAB and TXT versions are capable of being read and edited. An example of an environment file would be A123D.ENV representing ASW zone A123 and using data corresponding to the month of December.

In addition to the original 168 environment files created from FNOC data, there are a few generic environment files available. These generic files were created by modifying one of the 168 original files. There are three of these generic files being used currently by IBGTT/CSF, they are: KGOOD.ENV, KFAIR.ENV, and KPOOR.ENV.

B. REVIEWING THE ENVIRONMENT FILES

The environment file in the ENV filetype format cannot be printed in readable format. To read the environment file the operator must use the command ENV/PRINT. The ENV/PRINT command will prompt the operator for the filename of the desired environment file and then create a new file with the identical filename but a new filetype. The new filetype is

TAB. The new file, for example, A123D.TAB may then be printed, viewed on a monitor, and edited.

If the file is edited, in order for NWISS to use it in a game, the file must be changed into the operational code format (ENV filetype). To accomplish this, the operator must rename the file to change the filetype from TAB to TXT. This is done using the command RENAME <filename>.<filetype>. For example, RENAME A123D.TAB A123D.TXT.

The next step is to use the command ENV/BUILD. The ENV/BUILD command takes the environment file in the printable format with filetype TXT and creates a file in operational code with filetype ENV.

C. USE OF THE ENVIRONMENT FILES IN NWISS

Of the over 168 environment files available for use by NWISS a maximum of four can be utilized in one game. The environment files are selected by the operator based on the requirements for the scenario. Up to three of the environments can be defined by the logical names ENV\$GOOD, ENV\$FAIR, and ENV\$POOR in the appropriate NWISS directory. The fourth is defined at game initialization as the default region environment. Each environment is given a number to be used in the assignment of a particular environment file to a sonar region. The environment file which defines ENV\$GOOD is environment number one. The environment file which defines ENV\$FAIR is environment number two. The

environment which defines ENV\$POOR is environment number three and the default region environment is environment number four.

D. DEFINING SONAR REGIONS

NWISS allows the operator to define up to 20 environmental sonar regions. This is accomplished in the FORCE process during game scenario preparation. A region must have at least three sides and no more than six sides.

The boundaries of the region are defined by latitude/longitude position points. One point for each side of the region, i.e., a three sided sonar region would be defined by three lat/long positions, a four sided region by four lat/long positions, etc. The operator may define as many regions as required up to the limit of twenty. In addition, there is a default region automatically created which consists of all the area outside any of the defined sonar regions.

In defining a sonar region, the operator must also assign the environment to be used in that region. The operator has the choice of environment numbers one, two, or three, corresponding to the logical names ENV\$GOOD, ENV\$FAIR, ENV\$POOR, respectively. The default region will automatically be assigned environment number four.

E. SAMPLE ENVIRONMENT FILES

The following pages are the environment files used in describing the passive sonar model and the applications discussed in Chapter VI.

TABLE A-1

ENVIRONMENT FILE = LGOOD ENV

SONIC LAYER DEPTH = 164 feet

NUMBER OF FREQUENCIES = 20

NUMBER OF ACTIVE SONOBUOYS = 3

NUMBER OF ACTIVE SONARS = 24

FREQUENCIES (Hz):

10 15 20 30 40 60 80 100 125 250 315 630 900 1250 1600 2000 2500 3500 5000 10000

AMBIENT NOISE (dB):

72 75 76 75 75 74 73 70 66 67 67 65 63 60 59 57 55 54 48 45

ACTIVE SONOBUOY DATA:

Type	Range (nautical miles)
SSQ47	2.00
SSQ50	3.00
SSQ62	3.00

ACTIVE SONAR DATA: (depth in feet, ranges in nautical miles)

Type	Dip/Tow Depth	DP Range						BB Range Limits				CZ Limits	
		12 knots		18 knots		24 knots		Inner	Outer	Inner	Outer	Inner	Outer
		In	Deep	In	Deep	In	Deep						
AGS13	120	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARTIM	0	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BGG3A	0	12.0	3.0	12.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	31.0
BULLN	0	4.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BWOOD	0	2.0	1.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FENKM	0	3.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MAREM	0	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HQ311	0	3.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NEWCN	0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DQS01	0	4.0	3.0	4.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DQS3	0	4.0	3.0	4.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DQS4	0	4.0	2.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PEGA2	0	2.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SHRKF	0	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SHRKT	0	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SQ023	0	8.0	3.0	8.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	28.0	31.0
SQR26	0	4.0	3.0	4.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SQS23	0	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SQS26	0	12.0	3.0	12.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	31.0
SQS35	170	1.0	2.0	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SQS33	0	12.0	3.0	12.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	31.0
SQS56	0	3.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TAMR5	0	2.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TMR11	0	2.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE A-1
(Continued)

PROPAGATION LOSS DATA: (all values in dB)

	10 Hz				15 Hz				20 Hz				30 Hz				40 Hz			
Mile	In	Cross	Deep		In	Cross	Deep		In	Cross	Deep		In	Cross	Deep		In	Cross	Deep	
1	66.1	66.1	66.1		66.1	66.1	66.1		66.1	66.1	66.1		66.1	66.1	66.1		66.1	66.1	66.1	
2	72.1	72.1	72.1		72.1	72.1	72.1		72.1	72.1	72.1		72.1	72.1	72.1		72.1	72.1	72.1	
3	75.7	123.6	75.7		75.7	123.5	75.7		75.7	123.5	75.7		75.7	123.3	75.7		75.7	123.2	75.7	
4	124.4	124.4	78.2		124.3	124.3	78.2		124.3	124.2	78.2		124.1	124.1	78.2		123.9	123.9	78.2	
5	125.2	125.2	80.1		125.1	125.1	80.1		125.0	125.0	80.1		124.9	124.9	80.1		124.7	124.7	80.1	
6	126.0	126.0	81.7		125.9	125.9	81.7		125.9	125.8	81.7		125.7	125.7	81.7		125.5	125.5	81.7	
7	126.8	126.8	126.7		126.7	126.7	126.7		126.6	126.6	126.6		126.5	126.5	126.6		126.3	126.3	126.3	
8	127.6	127.5	127.5		127.5	127.5	127.4		127.4	127.4	127.4		127.3	127.2	127.2		127.1	127.1	127.1	
9	128.3	128.3	128.3		128.2	128.2	128.2		128.1	128.1	128.1		128.0	128.0	128.0		127.8	127.8	127.8	
10	129.0	129.0	129.0		128.9	128.9	128.9		128.8	128.8	128.8		128.7	128.7	128.6		128.5	128.5	128.5	
11	129.6	129.6	129.6		129.6	129.5	129.5		129.5	129.5	129.5		129.3	129.3	129.3		129.2	129.2	129.2	
12	130.3	130.2	130.2		130.2	130.2	130.2		130.1	130.1	130.1		130.0	129.9	129.9		129.8	129.8	129.8	
13	130.8	130.8	130.8		130.8	130.8	130.7		130.7	130.7	130.7		130.5	130.5	130.5		130.4	130.4	130.4	
14	131.2	131.1	131.1		131.1	131.1	131.0		131.0	131.0	130.9		130.9	130.8	130.8		130.7	130.7	130.6	
15	131.3	131.2	131.1		131.2	131.1	131.1		131.1	131.1	131.0		131.0	130.9	130.8		130.8	130.7	130.7	
16	131.3	131.3	131.2		131.3	131.2	131.1		131.2	131.1	131.1		131.0	131.0	130.9		130.9	130.8	130.8	
17	131.4	131.4	131.3		131.3	131.3	131.2		131.3	131.2	131.1		131.1	131.1	131.0		131.0	130.9	130.8	
18	131.5	131.4	131.4		131.4	131.4	131.3		131.3	131.3	131.2		131.2	131.1	131.1		131.0	131.0	130.9	
19	131.6	131.5	131.5		131.5	131.4	131.4		131.4	131.4	131.3		131.3	131.2	131.2		131.1	131.1	131.0	
20	131.6	131.6	131.5		131.6	131.5	131.5		131.5	131.4	131.4		131.3	131.3	131.2		131.2	131.1	131.1	
21	131.7	131.7	131.6		131.7	131.6	131.6		131.6	131.5	131.5		131.4	131.4	131.3		131.3	131.2	131.2	
22	131.8	131.8	131.7		131.7	131.7	131.6		131.7	131.6	131.6		131.5	131.5	131.4		131.4	131.3	131.3	
23	131.9	131.9	131.8		131.8	131.8	131.7		131.8	131.7	131.7		131.6	131.6	131.5		131.5	131.4	131.4	
24	132.0	131.9	131.9		131.9	131.9	131.8		131.8	131.8	131.7		131.7	131.6	131.6		131.5	131.5	131.4	
25	132.1	132.0	132.0		132.0	132.0	131.9		131.9	131.9	131.8		131.8	131.7	131.7		131.6	131.6	131.5	
26	132.2	132.1	132.1		132.1	132.1	132.0		132.0	132.0	131.9		131.9	131.8	131.8		131.7	131.7	131.6	
27	96.1	96.1	96.8		96.0	96.0	96.7		96.0	95.9	96.7		95.8	95.8	96.5		95.7	95.6	96.4	
28	96.2	96.2	96.9		96.1	96.1	96.9		96.1	96.1	96.8		95.9	95.9	96.6		95.8	95.7	96.5	
29	96.3	96.3	97.0		96.2	96.2	96.9		96.2	96.1	96.9		96.0	96.0	96.7		95.9	95.8	96.6	
30	96.4	96.4	97.1		96.3	96.3	97.0		96.3	96.2	97.0		96.1	96.1	96.8		95.9	95.9	96.7	
31	96.5	96.5	97.2		96.4	96.4	97.1		96.3	96.3	97.1		96.2	96.2	96.9		96.0	96.0	96.8	
32	96.6	96.6	97.3		96.5	96.5	97.2		96.4	96.4	97.2		96.3	96.3	97.0		96.1	96.1	96.9	
33	96.7	96.7	97.4		96.6	96.6	97.4		96.5	96.5	97.3		96.4	96.4	97.1		96.2	96.2	97.0	
34	96.8	96.8	97.5		96.7	96.7	97.4		96.6	96.6	97.4		96.5	96.5	97.2		96.3	96.3	97.1	
35	133.1	133.0	97.6		133.0	132.9	97.5		132.9	132.9	97.5		132.8	132.7	97.3		132.6	132.6	97.2	
36	133.2	133.1	133.1		133.1	133.0	133.0		133.0	133.0	132.9		132.9	132.8	132.8		132.7	132.7	132.6	
37	133.3	133.2	133.2		133.2	133.1	133.1		133.1	133.1	133.0		133.0	132.9	132.9		132.8	132.8	132.7	
38	133.4	133.3	133.3		133.3	133.2	133.2		133.2	133.2	133.1		133.1	133.0	133.0		132.9	132.9	132.8	
39	133.5	133.4	133.4		133.4	133.3	133.3		133.3	133.3	133.2		133.2	133.1	133.1		133.0	133.0	132.9	
40	133.5	133.5	133.5		133.5	133.4	133.4		133.4	133.4	133.3		133.3	133.2	133.2		133.1	133.1	133.0	
41	133.6	133.6	133.6		133.6	133.5	133.5		133.5	133.5	133.4		133.4	133.3	133.3		133.2	133.2	133.1	
42	133.7	133.7	133.7		133.7	133.6	133.6		133.6	133.6	133.5		133.4	133.4	133.4		133.3	133.3	133.2	
43	133.8	133.8	133.8		133.8	133.7	133.7		133.7	133.7	133.6		133.5	133.5	133.5		133.4	133.4	133.3	
44	133.9	133.9	133.9		133.9	133.8	133.8		133.8	133.8	133.7		133.6	133.6	133.6		133.5	133.5	133.4	
45	134.0	134.0	134.0		134.0	133.9	133.9		133.9	133.9	133.8		133.7	133.7	133.7		133.6	133.6	133.5	
46	134.1	134.1	134.1		134.1	134.0	134.0		134.0	134.0	133.9		133.8	133.8	133.8		133.7	133.7	133.6	
47	134.2	134.2	134.2		134.2	134.1	134.1		134.1	134.1	134.0		133.9	133.9	133.9		133.8	133.8	133.7	
48	134.3	134.3	134.3		134.3	134.2	134.2		134.2	134.2	134.1		134.0	134.0	134.0		133.9	133.9	133.8	
49	134.4	134.4	134.4		134.4	134.3	134.3		134.3	134.2	134.2		134.1	134.1	134.1		134.0	134.0	133.9	
50	134.5	134.5	134.5		134.4	134.4	134.4		134.4	134.3	134.3		134.2	134.2	134.2		134.1	134.0	134.0	
51	134.6	134.6	134.6		134.5	134.5	134.5		134.5	134.4	134.4		134.3	134.3	134.3		134.2	134.1	134.1	
52	134.7	134.7	134.7		134.6	134.6	134.6		134.6	134.5	134.5		134.4	134.4	134.4		134.3	134.2	134.2	
53	98.6	98.6	99.4		98.6	98.5	99.3		98.5	98.5	99.2		98.3	98.3	99.1		98.2	98.2	98.9	
54	98.7	98.7	99.5		98.7	98.6	99.4		98.6	98.6	99.3		98.4	98.4	99.2		98.3	98.3	99.0	
55	98.8	98.8	99.6		98.8	98.7	99.5		98.7	98.7	99.4		98.5	98.5	99.3		98.4	98.4	99.1	
56	98.9	98.9	99.7		98.8	98.8	99.6		98.8	98.7	99.5		98.6	98.6	99.4		98.5	98.4	99.2	
57	99.0	99.0	99.7		98.9	98.9	99.7		98.9	98.8	99.6		98.7	98.7	99.5		98.6	98.5	99.3	
58	99.1	99.1	99.8		99.0	99.0	99.8		99.0	98.9	99.7		98.8	98.8	99.5		98.7	98.6	99.4	
59	99.2	99.2	99.9		99.1	99.1	99.9		99.0	99.0	99.8		98.9	98.9	99.6		98.7	98.7	99.5	
60	99.3	99.3	100.0		99.2	99.2	99.9		99.1	99.1	99.9		99.0	99.0	99.7		98.8	98.8	99.6	

TABLE A-1
(Continued)

61	99 4	99 3	100 1	99 3	99 3	100 0	99 2	99 2	100 0	99 1	99 0	99 8	98 9	98 9	99 7
62	135 6	135 6	135 6	135 5	135 5	135 5	135 5	135 4	135 4	135 3	135 3	135 3	135 2	135 1	135 1
63	135 7	135 7	135 7	135 6	135 6	135 6	135 6	135 5	135 5	135 4	135 4	135 4	135 3	135 2	135 2
64	135 8	135 8	135 7	135 7	135 7	135 7	135 6	135 6	135 6	135 5	135 5	135 4	135 3	135 3	135 3
65	135 9	135 8	135 8	135 8	135 8	135 8	135 7	135 7	135 7	135 6	135 5	135 5	135 4	135 4	135 4
66	136 0	135 9	135 9	135 9	135 9	135 8	135 8	135 8	135 8	135 7	135 6	135 6	135 5	135 5	135 5
67	136 0	136 0	136 0	136 0	135 9	135 9	135 9	135 8	135 8	135 7	135 7	135 7	135 6	135 6	135 6
68	136 1	136 1	136 1	136 1	136 0	136 0	136 0	135 9	135 9	135 8	135 8	135 8	135 7	135 7	135 6
69	136 2	136 2	136 2	136 1	136 1	136 1	136 1	136 0	136 0	135 9	135 9	135 9	135 8	135 7	135 7
70	136 3	136 3	136 2	136 2	136 2	136 2	136 1	136 1	136 1	136 0	136 0	136 0	135 9	135 8	135 8
71	136 4	136 4	136 3	136 3	136 3	136 3	136 2	136 2	136 2	136 1	136 1	136 0	135 9	135 9	135 9
72	136 5	136 4	136 4	136 4	136 4	136 3	136 3	136 3	136 3	136 2	136 1	136 1	136 0	136 0	136 0
73	136 5	136 5	136 5	136 5	136 4	136 4	136 4	136 3	136 3	136 2	136 2	136 2	136 1	136 1	136 1
74	136 6	136 6	136 6	136 5	136 5	136 5	136 5	136 4	136 4	136 3	136 3	136 3	136 2	136 2	136 1
75	136 7	136 7	136 7	136 6	136 6	136 6	136 5	136 5	136 5	136 4	136 4	136 4	136 3	136 2	136 2
76	136 8	136 8	136 7	136 7	136 7	136 7	136 6	136 6	136 6	136 5	136 5	136 4	136 3	136 3	136 3
77	136 9	136 8	136 8	136 8	136 8	136 7	136 7	136 7	136 7	136 6	136 5	136 5	136 4	136 4	136 4
78	136 9	136 9	136 9	136 9	136 8	136 8	136 8	136 7	136 7	136 6	136 6	136 6	136 5	136 5	136 5
79	137 0	137 0	137 0	136 9	136 9	136 9	136 9	136 8	136 8	136 7	136 7	136 7	136 6	136 6	136 5
80	137 1	137 1	137 0	137 0	137 0	137 0	136 9	136 9	136 9	136 8	136 8	136 8	136 6	136 6	136 6
81	137 2	137 1	137 1	137 1	137 1	137 0	137 0	137 0	137 0	136 9	136 8	136 8	136 7	136 7	136 7
82	137 2	137 2	137 2	137 2	137 1	137 1	137 1	137 0	137 0	136 9	136 9	136 9	136 8	136 8	136 8
83	137 3	137 3	137 3	137 2	137 2	137 2	137 2	137 1	137 1	137 0	137 0	137 0	136 9	136 9	136 8
84	137 4	137 4	137 3	137 3	137 3	137 3	137 2	137 2	137 2	137 1	137 1	137 1	136 9	136 9	136 9
85	137 5	137 4	137 4	137 4	137 4	137 3	137 3	137 3	137 3	137 2	137 1	137 1	137 0	137 0	137 0
86	137 5	137 5	137 5	137 5	137 4	137 4	137 4	137 4	137 3	137 2	137 2	137 2	137 1	137 1	137 1
87	137 6	137 6	137 6	137 5	137 5	137 5	137 5	137 4	137 4	137 3	137 3	137 3	137 2	137 2	137 1
88	137 7	137 7	137 6	137 6	137 6	137 6	137 5	137 5	137 5	137 4	137 4	137 3	137 2	137 2	137 2
89	137 7	137 7	137 7	137 7	137 7	137 6	137 6	137 6	137 6	137 5	137 4	137 4	137 3	137 3	137 3
90	137 8	137 8	137 8	137 7	137 7	137 7	137 7	137 7	137 6	137 5	137 5	137 5	137 4	137 4	137 3
91	137 9	137 9	137 9	137 8	137 8	137 8	137 7	137 7	137 7	137 6	137 6	137 6	137 5	137 4	137 4
92	138 0	137 9	137 9	137 9	137 8	137 8	137 8	137 8	137 8	137 7	137 7	137 6	137 5	137 5	137 5
93	138 0	138 0	138 0	138 0	137 9	137 9	137 9	137 9	137 8	137 7	137 7	137 7	137 6	137 6	137 6
94	138 1	138 1	138 1	138 0	138 0	138 0	137 9	137 9	137 9	137 8	137 8	137 8	137 7	137 6	137 6
95	138 2	138 1	138 1	138 1	138 1	138 1	138 0	138 0	138 0	137 9	137 9	137 8	137 7	137 7	137 7
96	138 2	138 2	138 2	138 2	138 1	138 1	138 1	138 1	138 1	137 9	137 9	137 9	137 8	137 8	137 8
97	138 3	138 3	138 3	138 2	138 2	138 2	138 2	138 1	138 1	138 0	138 0	138 0	137 9	137 9	137 8
98	138 4	138 3	138 3	138 3	138 3	138 3	138 2	138 2	138 2	138 1	138 1	138 0	137 9	137 9	137 9
99	138 4	138 4	138 4	138 4	138 3	138 3	138 3	138 3	138 3	138 2	138 1	138 1	138 0	138 0	138 0
100	138 5	138 5	138 5	138 4	138 4	138 4	138 4	138 3	138 3	138 2	138 2	138 2	138 1	138 1	138 0
101	138 6	138 5	138 5	138 5	138 5	138 5	138 4	138 4	138 4	138 3	138 3	138 2	138 1	138 1	138 1
102	138 6	138 6	138 6	138 6	138 5	138 5	138 5	138 5	138 5	138 4	138 3	138 3	138 2	138 2	138 2
103	138 7	138 7	138 7	138 6	138 6	138 6	138 5	138 5	138 5	138 4	138 4	138 4	138 3	138 3	138 2
104	138 8	138 7	138 7	138 7	138 7	138 7	138 6	138 6	138 6	138 5	138 5	138 4	138 3	138 3	138 3
105	138 8	138 8	138 8	138 7	138 7	138 7	138 7	138 7	138 6	138 5	138 5	138 5	138 4	138 4	138 4
106	138 9	138 9	138 9	138 8	138 8	138 8	138 7	138 7	138 7	138 6	138 6	138 6	138 5	138 4	138 4
107	138 9	138 9	138 9	138 9	138 9	138 8	138 8	138 8	138 8	138 7	138 6	138 6	138 5	138 5	138 5
108	139 0	139 0	139 0	138 9	138 9	138 9	138 9	138 8	138 8	138 7	138 7	138 7	138 6	138 6	138 6
109	139 1	139 1	139 0	139 0	139 0	139 0	138 9	138 9	138 9	138 8	138 8	138 8	138 6	138 6	138 6
110	139 1	139 1	139 1	139 1	139 0	139 0	139 0	139 0	139 0	138 8	138 8	138 8	138 7	138 7	138 7
111	139 2	139 2	139 2	139 1	139 1	139 1	139 1	139 0	139 0	138 9	138 9	138 9	138 8	138 8	138 7
112	139 3	139 2	139 2	139 2	139 2	139 2	139 1	139 1	139 1	139 0	139 0	138 9	138 8	138 8	138 8
113	139 3	139 3	139 3	139 2	139 2	139 2	139 2	139 2	139 1	139 0	139 0	139 0	138 9	138 9	138 8
114	139 4	139 4	139 4	139 3	139 3	139 3	139 2	139 2	139 2	139 1	139 1	139 1	139 0	138 9	138 9
115	139 4	139 4	139 4	139 4	139 3	139 3	139 3	139 3	139 3	139 2	139 1	139 1	139 0	139 0	139 0
116	139 5	139 5	139 5	139 4	139 4	139 4	139 4	139 3	139 3	139 2	139 2	139 2	139 1	139 1	139 0
117	139 6	139 5	139 5	139 5	139 5	139 5	139 4	139 4	139 4	139 3	139 3	139 2	139 2	139 1	139 1
118	139 6	139 6	139 6	139 5	139 5	139 5	139 5	139 4	139 4	139 3	139 3	139 3	139 2	139 2	139 2
119	139 7	139 7	139 6	139 6	139 6	139 6	139 5	139 5	139 5	139 4	139 4	139 4	139 2	139 2	139 2
120	139 7	139 7	139 7	139 6	139 6	139 6	139 6	139 6	139 6	139 4	139 4	139 4	139 3	139 3	139 3

TABLE A-1
(Continued)

Mile	60 Hz				80 Hz				100 Hz				125 Hz				250 Hz			
	In	Cross	Deep		In	Cross	Deep		In	Cross	Deep		In	Cross	Deep		In	Cross	Deep	
1	66.1	66.1	66.1		66.0	66.1	66.1		65.7	66.1	66.1		65.2	66.1	66.1		63.6	66.1	66.1	
2	72.2	72.2	72.2		72.1	72.2	72.2		72.1	72.2	72.2		71.8	72.2	72.2		69.5	72.2	72.2	
3	75.7	122.8	75.7		75.7	122.5	75.7		75.7	122.2	75.7		75.6	121.7	75.7		73.4	120.7	75.7	
4	123.6	123.6	78.2		123.0	123.3	78.2		114.2	122.9	78.2		101.3	122.5	78.2		81.3	121.5	78.2	
5	124.4	124.4	80.1		124.1	124.1	80.1		122.0	123.7	80.1		109.9	123.3	80.1		85.0	122.3	80.2	
6	125.2	125.2	81.7		124.9	124.9	81.7		124.4	124.5	81.7		117.5	124.1	81.7		88.5	123.1	81.8	
7	126.0	126.0	126.0		125.7	125.7	125.6		125.3	125.3	125.3		122.8	124.9	124.9		91.9	123.9	123.9	
8	126.8	126.8	126.7		126.5	126.4	126.4		126.1	126.1	126.1		125.2	125.7	125.6		95.2	124.7	124.7	
9	127.5	127.5	127.5		127.2	127.2	127.2		126.8	126.8	126.8		126.3	126.4	126.4		98.4	125.5	125.4	
10	128.2	128.2	128.2		127.9	127.9	127.9		127.5	127.5	127.5		127.1	127.1	127.1		101.6	126.2	126.1	
11	128.9	128.9	128.8		128.5	128.5	128.5		128.2	128.2	128.2		127.8	127.7	127.7		104.7	126.8	126.8	
12	129.5	129.5	129.5		129.2	129.1	129.1		128.8	128.8	128.8		128.4	128.4	128.4		107.8	127.5	127.4	
13	130.1	130.1	130.1		129.7	129.7	129.7		129.4	129.4	129.4		129.0	129.0	129.0		110.8	128.1	128.0	
14	130.4	130.4	130.3		130.1	130.0	130.0		129.8	129.7	129.6		129.3	129.3	129.2		113.8	128.6	128.6	
15	130.5	130.4	130.4		130.2	130.1	130.1		129.8	129.8	129.7		129.4	129.3	129.3		116.7	129.2	129.2	
16	130.6	130.5	130.5		130.2	130.2	130.1		129.9	129.9	129.8		129.5	129.4	129.4		119.5	129.7	129.7	
17	130.6	130.6	130.5		130.3	130.3	130.2		130.0	129.9	129.9		129.6	129.5	129.4		122.2	130.2	130.2	
18	130.7	130.7	130.6		130.4	130.3	130.3		130.1	130.0	130.0		129.6	129.6	129.5		124.6	130.6	130.6	
19	130.8	130.7	130.7		130.5	130.4	130.4		130.1	130.1	130.0		129.7	129.7	129.6		126.8	131.1	131.1	
20	130.9	130.8	130.8		130.6	130.5	130.5		130.2	130.2	130.1		129.8	129.7	129.7		128.6	131.5	131.5	
21	131.0	130.9	130.9		130.6	130.6	130.5		130.3	130.3	130.2		129.9	129.8	129.8		130.1	131.9	131.9	
22	131.1	131.0	131.0		130.7	130.7	130.6		130.4	130.4	130.3		130.0	129.9	129.9		131.2	132.3	132.3	
23	131.1	131.1	131.0		130.8	130.8	130.7		130.5	130.4	130.4		130.1	130.0	130.0		132.0	132.7	132.7	
24	131.2	131.2	131.1		130.9	130.9	130.8		130.6	130.5	130.5		130.2	130.1	130.1		132.7	133.0	133.0	
25	131.3	131.3	131.2		131.0	131.0	130.9		130.7	130.6	130.6		130.3	130.2	130.2		133.2	133.4	133.4	
26	131.4	131.4	131.3		131.1	131.1	131.0		130.8	130.7	130.7		130.3	130.3	130.3		133.6	133.7	133.7	
27	95.4	95.3	96.1		95.0	95.0	95.7		94.7	94.7	95.4		94.3	94.2	95.0		97.8	97.9	98.7	
28	95.4	95.4	96.2		95.1	95.1	95.8		94.8	94.8	95.5		94.4	94.3	95.1		98.2	98.2	99.0	
29	95.5	95.5	96.2		95.2	95.2	95.9		94.9	94.9	95.6		94.5	94.4	95.2		98.5	98.5	99.3	
30	95.6	95.6	96.3		95.3	95.3	96.0		95.0	95.0	95.7		94.6	94.5	95.3		98.8	98.8	99.6	
31	95.7	95.7	96.4		95.4	95.4	96.1		95.1	95.1	95.8		94.7	94.6	95.4		98.8	98.7	99.4	
32	95.8	95.8	96.5		95.5	95.5	96.2		95.2	95.2	95.9		94.8	94.7	95.5		98.7	98.6	99.3	
33	95.9	95.9	96.7		95.6	95.6	96.3		95.3	95.3	96.0		94.9	94.8	95.6		98.6	98.5	99.2	
34	96.0	96.0	96.8		95.7	95.7	96.4		95.4	95.4	96.1		95.0	94.9	95.7		98.5	98.4	99.1	
35	132.3	132.2	96.9		132.0	131.9	96.5		131.7	131.6	96.2		131.3	131.2	95.8		134.6	134.5	99.0	
36	132.4	132.4	132.3		132.1	132.0	132.0		131.8	131.7	131.7		131.4	131.3	131.3		134.5	134.4	134.3	
37	132.5	132.5	132.4		132.2	132.1	132.1		131.9	131.8	131.8		131.5	131.4	131.4		134.4	134.3	134.2	
38	132.6	132.6	132.5		132.3	132.3	132.2		132.0	131.9	131.9		131.6	131.5	131.5		134.3	134.2	134.2	
39	132.7	132.7	132.6		132.4	132.4	132.3		132.1	132.0	132.0		131.7	131.6	131.6		134.3	134.2	134.1	
40	132.8	132.8	132.7		132.5	132.5	132.4		132.2	132.1	132.1		131.8	131.7	131.7		134.2	134.1	134.1	
41	132.9	132.9	132.8		132.6	132.6	132.5		132.3	132.2	132.2		131.9	131.8	131.8		134.2	134.1	134.0	
42	133.0	133.0	132.9		132.7	132.7	132.6		132.4	132.3	132.3		132.0	131.9	131.9		134.1	134.1	134.0	
43	133.1	133.1	133.0		132.8	132.8	132.7		132.5	132.4	132.4		132.1	132.0	132.0		134.1	134.0	133.9	
44	133.2	133.2	133.1		132.9	132.9	132.8		132.6	132.5	132.5		132.2	132.1	132.1		134.1	134.0	133.9	
45	133.3	133.3	133.2		133.0	133.0	132.9		132.7	132.6	132.6		132.3	132.2	132.2		134.0	134.0	133.9	
46	133.4	133.4	133.3		133.1	133.1	133.0		132.8	132.7	132.7		132.4	132.3	132.3		134.0	134.0	133.9	
47	133.5	133.5	133.4		133.2	133.2	133.1		132.9	132.8	132.8		132.5	132.4	132.4		134.0	133.9	133.9	
48	133.6	133.6	133.5		133.3	133.2	133.2		133.0	132.9	132.9		132.6	132.5	132.5		134.0	133.9	133.9	
49	133.7	133.7	133.6		133.4	133.3	133.3		133.1	133.0	133.0		132.7	132.6	132.6		134.0	133.9	133.9	
50	133.8	133.7	133.7		133.5	133.4	133.4		133.2	133.1	133.1		132.8	132.7	132.7		134.0	133.9	133.9	
51	133.9	133.8	133.8		133.6	133.5	133.5		133.3	133.2	133.2		132.9	132.8	132.8		134.0	133.9	133.9	
52	134.0	133.9	133.9		133.7	133.6	133.6		133.4	133.3	133.3		133.0	132.9	132.9		134.0	133.9	133.9	
53	97.9	97.9	98.6		97.6	97.6	98.3		97.3	97.3	98.0		96.9	96.9	97.6		97.8	97.8	98.5	
54	98.0	98.0	98.0		97.7	97.7	98.4		97.4	97.4	98.1		97.0	97.0	97.7		97.9	97.8	98.5	
55	98.1	98.1	98.8		97.8	97.8	98.5		97.5	97.4	98.2		97.1	97.1	97.8		97.9	97.8	98.5	
56	98.2	98.1	98.9		97.9	97.8	98.6		97.6	97.5	98.3		97.2	97.2	97.9		97.9	97.8	98.6	
57	98.3	98.2	99.0		98.0	97.9	98.7		97.7	97.6	98.4		97.3	97.2	98.0		97.9	97.8	98.6	

TABLE A-1
(Continued)

58	98.4	98.3	99.1	98.1	98.0	98.8	97.8	97.7	98.5	97.4	97.3	98.1	97.9	97.9	98.6
59	98.4	98.4	99.2	98.1	98.1	98.9	97.8	97.8	98.6	97.5	97.4	98.2	97.9	97.9	98.6
60	98.5	98.5	99.3	98.2	98.2	99.0	97.9	97.9	98.7	97.5	97.5	98.3	98.0	97.9	98.6
61	98.6	98.6	99.4	98.3	98.3	99.1	98.0	98.0	99.1	97.6	97.6	98.4	98.0	97.9	98.7
62	134.9	134.9	134.8	134.6	134.6	134.5	134.3	134.3	134.2	133.9	133.9	133.8	134.2	134.1	134.1
63	135.0	134.9	134.9	134.7	134.6	134.6	134.4	134.3	134.3	134.0	134.0	133.9	134.2	134.1	134.1
64	135.1	135.0	135.0	134.8	134.7	134.7	134.5	134.4	134.4	134.1	134.0	134.0	134.2	134.2	134.1
65	135.1	135.1	135.1	134.8	134.8	134.8	134.5	134.5	134.5	134.2	134.1	134.1	134.3	134.2	134.2
66	135.2	135.2	135.2	134.9	134.9	134.9	134.6	134.6	134.6	134.2	134.2	134.2	134.3	134.2	134.2
67	135.3	135.3	135.3	135.0	135.0	135.0	134.7	134.7	134.7	134.3	134.3	134.3	134.3	134.3	134.2
68	135.4	135.4	135.3	135.1	135.1	135.1	134.8	134.8	134.8	134.4	134.4	134.4	134.4	134.3	134.3
69	135.5	135.5	135.4	135.2	135.2	135.1	134.9	134.9	134.8	134.5	134.5	134.5	134.4	134.3	134.3
70	135.6	135.5	135.5	135.3	135.2	135.2	135.0	134.9	134.9	134.6	134.6	134.6	134.4	134.4	134.3
71	135.6	135.6	135.6	135.3	135.3	135.3	135.1	135.0	135.0	134.7	134.7	134.6	134.5	134.4	134.4
72	135.7	135.7	135.7	135.4	135.4	135.4	135.1	135.1	135.1	134.8	134.7	134.7	134.5	134.5	134.4
73	135.8	135.8	135.8	135.5	135.5	135.5	135.2	135.2	135.2	134.8	134.8	134.8	134.5	134.5	134.4
74	135.9	135.9	135.8	135.6	135.6	135.6	135.3	135.3	135.3	134.9	134.9	134.9	134.6	134.5	134.5
75	136.0	135.9	135.9	135.7	135.7	135.6	135.4	135.4	135.3	135.0	135.0	135.0	134.6	134.6	134.5
76	136.0	136.0	136.0	135.8	135.7	135.7	135.5	135.4	135.4	135.1	135.1	135.1	134.7	134.6	134.6
77	136.1	136.1	136.1	135.8	135.8	135.8	135.5	135.5	135.5	135.2	135.2	135.1	134.7	134.7	134.6
78	136.2	136.2	136.2	135.9	135.9	135.9	135.6	135.6	135.6	135.3	135.2	135.2	134.7	134.7	134.7
79	136.3	136.3	136.2	136.0	136.0	136.0	135.7	135.7	135.7	135.3	135.3	135.3	134.8	134.7	134.7
80	136.4	136.3	136.3	136.1	136.1	136.0	135.8	135.8	135.7	135.4	135.4	135.4	134.8	134.8	134.7
81	136.4	136.4	136.4	136.1	136.1	136.1	135.9	135.8	135.8	135.5	135.5	135.5	134.9	134.8	134.8
82	136.5	136.5	136.5	136.2	136.2	136.2	135.9	135.9	135.9	135.6	135.6	135.5	134.9	134.9	134.8
83	136.6	136.6	136.6	136.3	136.3	136.3	136.0	136.0	136.0	135.7	135.6	135.6	135.0	134.9	134.9
84	136.7	136.6	136.6	136.4	136.4	136.3	136.1	136.1	136.1	135.7	135.7	135.7	135.0	135.0	134.9
85	136.7	136.7	136.7	136.4	136.4	136.4	136.2	136.1	136.1	135.8	135.8	135.8	135.1	135.0	135.0
86	136.8	136.8	136.8	136.5	136.5	136.5	136.2	136.2	136.2	135.9	135.9	135.8	135.1	135.1	135.0
87	136.9	136.9	136.8	136.6	136.6	136.6	136.3	136.3	136.3	136.0	135.9	135.9	135.1	135.1	135.1
88	137.0	136.9	136.9	136.7	136.7	136.6	136.4	136.4	136.4	136.0	136.0	136.0	135.2	135.2	135.1
89	137.0	137.0	137.0	136.7	136.7	136.7	136.5	136.4	136.4	136.1	136.1	136.1	135.2	135.2	135.2
90	137.1	137.1	137.1	136.8	136.8	136.8	136.5	136.5	136.5	136.2	136.2	136.1	135.3	135.2	135.2
91	137.2	137.2	137.1	136.9	136.9	136.9	136.6	136.6	136.6	136.3	136.2	136.2	135.3	135.3	135.3
92	137.2	137.2	137.2	137.0	136.9	136.9	136.7	136.7	136.6	136.3	136.3	136.3	135.4	135.3	135.3
93	137.3	137.3	137.3	137.0	137.0	137.0	136.7	136.7	136.7	136.4	136.4	136.4	135.4	135.4	135.4
94	137.4	137.4	137.3	137.1	137.1	137.1	136.8	136.8	136.8	136.5	136.5	136.4	135.5	135.4	135.4
95	137.4	137.4	137.4	137.2	137.2	137.1	136.9	136.9	136.9	136.5	136.5	136.5	135.5	135.5	135.4
96	137.5	137.5	137.5	137.2	137.2	137.2	137.0	136.9	136.9	136.6	136.6	136.6	135.6	135.5	135.5
97	137.6	137.6	137.6	137.3	137.3	137.3	137.0	137.0	137.0	136.7	136.7	136.7	135.6	135.6	135.5
98	137.7	137.6	137.6	137.4	137.4	137.3	137.1	137.1	137.1	136.8	136.7	136.7	135.7	135.6	135.6
99	137.7	137.7	137.7	137.4	137.4	137.4	137.2	137.2	137.1	136.8	136.8	136.8	135.7	135.7	135.6
100	137.8	137.8	137.8	137.5	137.5	137.5	137.2	137.2	137.2	136.9	136.9	136.9	135.8	135.7	135.7
101	137.9	137.8	137.8	137.6	137.6	137.5	137.3	137.3	137.3	137.0	136.9	136.9	135.8	135.8	135.7
102	137.9	137.9	137.9	137.6	137.6	137.6	137.4	137.4	137.3	137.0	137.0	137.0	135.9	135.8	135.8
103	138.0	138.0	138.0	137.7	137.7	137.7	137.4	137.4	137.4	137.1	137.1	137.1	135.9	135.9	135.8
104	138.0	138.0	138.0	137.8	137.8	137.8	137.5	137.5	137.5	137.2	137.2	137.1	136.0	135.9	135.9
105	138.1	138.1	138.1	137.8	137.8	137.8	137.6	137.6	137.5	137.2	137.2	137.2	136.0	136.0	135.9
106	138.2	138.2	138.2	137.9	137.9	137.9	137.6	137.6	137.6	137.3	137.3	137.3	136.1	136.0	136.0
107	138.2	138.2	138.2	138.0	138.0	137.9	137.7	137.7	137.7	137.4	137.4	137.3	136.1	136.1	136.0
108	138.3	138.3	138.3	138.0	138.0	138.0	137.8	137.8	137.7	137.4	137.4	137.4	136.2	136.1	136.1
109	138.4	138.4	138.3	138.1	138.1	138.1	137.8	137.8	137.8	137.5	137.5	137.5	136.2	136.2	136.1
110	138.4	138.4	138.4	138.2	138.1	138.1	137.9	137.9	137.9	137.6	137.5	137.5	136.3	136.2	136.2
111	138.5	138.5	138.5	138.2	138.2	138.2	138.0	137.9	137.9	137.6	137.6	137.6	136.3	136.3	136.2
112	138.6	138.5	138.5	138.3	138.3	138.3	138.0	138.0	138.0	137.7	137.7	137.7	136.4	136.3	136.3
113	138.6	138.6	138.6	138.3	138.3	138.3	138.1	138.1	138.1	137.8	137.7	137.7	136.4	136.4	136.3
114	138.7	138.7	138.7	138.4	138.4	138.4	138.1	138.1	138.1	137.8	137.8	137.8	136.5	136.4	136.4
115	138.7	138.7	138.7	138.5	138.5	138.4	138.2	138.2	138.2	137.9	137.9	137.9	136.5	136.5	136.5
116	138.8	138.8	138.8	138.5	138.5	138.5	138.3	138.3	138.2	137.9	137.9	137.9	136.6	136.6	136.6
117	138.9	138.8	138.8	138.6	138.6	138.6	138.3	138.3	138.3	138.0	138.0	138.0	136.7	136.7	136.7
118	138.9	138.9	138.9	138.7	138.6	138.6	138.4	138.4	138.4	138.1	138.1	138.0	136.8	136.8	136.8
119	139.0	139.0	139.0	138.8	138.8	138.8	138.5	138.5	138.5	138.2	138.2	138.2	136.9	136.9	136.9
120	139.0	139.0	139.0	138.8	138.8	138.8	138.5	138.5	138.5	138.2	138.2	138.2	136.9	136.9	136.9

TABLE A-1
(Continued)

	315 Hz			630 Hz			900 Hz			1250 Hz			1600 Hz		
Mile	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep
1	66.3	66.1	66.1	66.2	66.2	66.2	66.2	66.2	66.2	66.3	66.3	66.3	66.3	66.3	66.3
2	68.8	72.2	72.2	72.3	72.3	72.3	72.3	72.3	72.3	72.4	72.4	72.4	72.4	72.4	72.4
3	72.4	120.8	75.7	75.8	121.0	75.8	75.9	120.9	75.9	76.0	136.5	76.0	76.1	136.6	76.1
4	78.5	121.5	78.2	121.8	121.8	78.4	121.8	121.7	78.5	137.4	137.3	78.7	137.5	137.5	78.7
5	81.4	122.4	80.2	122.7	122.6	80.6	122.6	122.6	80.6	138.2	138.2	80.7	138.4	138.4	80.8
6	84.2	123.2	81.8	123.5	123.5	82.0	123.5	123.4	82.2	139.1	139.1	82.4	139.3	139.3	82.6
7	86.9	124.0	124.0	124.4	124.3	124.3	124.3	124.3	124.3	140.0	140.0	140.0	140.2	140.2	140.2
8	89.5	124.8	124.8	125.2	125.1	125.1	125.2	125.1	125.1	140.9	140.9	140.8	141.1	141.1	141.0
9	92.1	125.5	125.5	125.9	125.9	125.9	126.0	126.0	125.9	141.7	141.7	141.7	141.9	141.9	141.9
10	94.5	126.2	126.2	126.7	126.7	126.7	126.7	126.7	126.7	142.5	142.5	142.5	142.8	142.7	142.7
11	96.9	126.9	126.9	127.4	127.4	127.4	127.5	127.5	127.5	143.3	143.3	143.2	143.5	143.5	143.5
12	99.3	127.5	127.5	128.1	128.0	128.0	128.2	128.2	128.2	144.0	144.0	144.0	144.3	144.3	144.3
13	101.7	128.1	128.1	128.7	128.7	128.7	128.8	128.8	128.8	144.7	144.7	144.7	145.0	145.0	145.0
14	104.0	128.7	128.7	129.3	129.3	129.3	129.5	129.5	129.5	145.4	145.4	145.3	145.7	145.7	145.7
15	106.3	129.3	129.3	129.9	129.9	129.9	130.1	130.1	130.1	146.0	146.0	146.0	146.3	146.3	146.3
16	108.6	129.8	129.8	130.4	130.4	130.4	130.7	130.7	130.7	146.6	146.6	146.6	147.0	147.0	147.0
17	110.9	130.3	130.3	131.0	131.0	131.0	131.2	131.2	131.2	147.2	147.2	147.2	147.6	147.6	147.6
18	113.1	130.7	130.7	131.5	131.5	131.5	131.8	131.8	131.8	147.8	147.8	147.8	148.2	148.2	148.2
19	115.3	131.2	131.2	132.0	132.0	132.0	132.3	132.3	132.3	148.3	148.3	148.3	148.8	148.8	148.8
20	117.5	131.6	131.6	132.4	132.4	132.4	132.8	132.8	132.8	148.9	148.9	148.9	149.3	149.3	149.3
21	119.6	132.0	132.0	132.9	132.9	132.9	133.3	133.3	133.3	149.4	149.4	149.4	149.9	149.9	149.9
22	121.7	132.4	132.4	133.3	133.3	133.3	133.8	133.7	133.7	149.9	149.9	149.9	150.4	150.4	150.4
23	123.8	132.8	132.8	133.7	133.7	133.7	134.2	134.2	134.2	150.4	150.4	150.4	150.9	150.9	150.9
24	125.7	133.2	133.2	134.1	134.1	134.1	134.6	134.6	134.6	150.8	150.8	150.8	151.4	151.4	151.4
25	127.5	133.5	133.5	134.5	134.5	134.5	135.1	135.1	135.1	151.3	151.3	151.3	151.9	151.8	151.8
26	129.1	133.9	133.9	134.9	134.9	134.9	135.5	135.5	135.5	151.7	151.7	151.7	152.3	152.3	152.3
27	94.4	98.1	98.9	99.1	99.1	99.9	99.7	99.7	100.5	116.0	116.0	116.8	116.6	116.6	117.4
28	95.7	98.4	99.2	99.5	99.5	100.3	100.1	100.1	100.9	116.4	116.4	117.2	117.1	117.1	117.8
29	96.8	98.7	99.5	99.8	99.8	100.6	100.5	100.5	101.3	116.8	116.8	117.6	117.5	117.5	118.3
30	97.7	99.0	99.8	100.2	100.2	100.9	100.9	100.9	101.7	117.3	117.3	118.0	117.9	117.9	118.7
31	98.2	98.9	99.6	100.2	100.1	100.8	101.2	101.2	102.0	117.7	117.6	118.4	118.3	118.3	119.1
32	98.4	98.8	99.5	100.2	100.1	100.8	101.6	101.6	102.4	118.0	118.0	118.8	118.7	118.7	119.5
33	98.5	98.7	99.4	100.1	100.0	100.7	101.9	101.9	102.7	118.4	118.4	119.2	119.2	119.1	119.9
34	98.5	98.6	99.3	100.0	99.9	100.6	102.3	102.3	103.1	118.8	118.8	119.6	119.5	119.5	120.3
35	134.7	134.7	99.2	136.1	136.1	100.6	138.6	138.6	103.1	155.3	155.3	119.9	156.1	156.1	120.7
36	134.6	134.6	134.5	136.1	136.0	135.9	138.7	138.6	138.5	155.7	155.7	155.7	156.5	156.5	156.5
37	134.6	134.5	134.5	136.1	136.0	135.9	138.7	138.6	138.5	156.0	156.0	156.0	156.9	156.8	156.8
38	134.5	134.5	134.5	136.1	136.0	135.9	138.7	138.6	138.5	156.4	156.4	156.4	157.2	157.2	157.2
39	134.5	134.4	134.3	136.0	136.0	135.9	138.7	138.6	138.6	156.7	156.7	156.7	157.6	157.6	157.6
40	134.5	134.4	134.3	136.0	136.0	135.9	138.8	138.7	138.6	157.1	157.1	157.1	157.9	157.9	157.9
41	134.4	134.3	134.3	136.0	136.0	135.9	138.8	138.7	138.6	157.4	157.4	157.4	158.3	158.3	158.3
42	134.4	134.3	134.2	136.0	136.0	135.9	138.8	138.8	138.7	157.7	157.7	157.7	158.6	158.6	158.6
43	134.4	134.3	134.2	136.1	136.0	135.9	138.9	138.8	138.7	158.0	158.0	158.0	159.0	159.0	159.0
44	134.3	134.3	134.2	136.1	136.0	135.9	139.0	138.9	138.8	158.4	158.4	158.4	159.3	159.3	159.3
45	134.3	134.3	134.2	136.1	136.0	135.9	139.0	138.9	138.9	158.7	158.7	158.7	159.7	159.7	159.7
46	134.3	134.2	134.2	136.1	136.0	136.0	139.1	139.0	138.9	159.0	159.0	159.0	160.0	160.0	160.0
47	134.3	134.2	134.2	136.1	136.1	136.0	139.2	139.1	139.0	159.3	159.3	159.3	160.3	160.3	160.3
48	134.3	134.2	134.2	136.2	136.1	136.0	139.2	139.2	139.1	159.6	159.6	159.6	160.6	160.6	160.6
49	134.3	134.2	134.2	136.2	136.1	136.1	139.3	139.2	139.2	159.9	159.9	159.9	161.0	161.0	161.0
50	134.3	134.2	134.2	136.3	136.2	136.1	139.4	139.3	139.3	160.2	160.2	160.2	161.3	161.3	161.3
51	134.3	134.3	134.2	136.3	136.2	136.2	139.5	139.4	139.3	160.5	160.5	160.5	161.6	161.6	161.6
52	134.3	134.3	134.2	136.4	136.3	136.2	139.6	139.5	139.4	160.8	160.8	160.8	161.9	161.9	161.9
53	98.2	98.1	98.8	100.2	100.2	100.9	103.5	103.4	104.2	124.9	124.9	125.7	126.0	126.0	126.8
54	98.2	98.1	98.9	100.3	100.2	101.0	103.6	103.5	104.3	125.2	125.2	126.0	126.4	126.4	127.1

TABLE A-1
(Continued)

55	98.2	98.2	98.9	100.4	100.3	101.0	103.7	103.6	104.3	125.4	125.4	126.2	126.7	126.7	127.4
56	98.2	98.2	98.9	100.4	100.4	101.1	103.8	103.7	104.4	125.7	125.7	126.5	127.0	127.0	127.7
57	98.3	98.2	98.9	100.5	100.4	101.1	103.9	103.8	104.5	126.0	126.0	126.8	127.2	127.2	128.0
58	98.3	98.2	99.0	100.5	100.5	101.2	104.0	103.9	104.7	126.3	126.3	127.1	127.5	127.5	128.3
59	98.3	98.3	99.0	100.6	100.5	101.3	104.1	104.0	104.8	126.5	126.5	127.3	127.8	127.8	128.6
60	98.3	98.3	99.0	100.7	100.6	101.4	104.2	104.1	104.9	126.8	126.8	127.6	128.1	128.1	128.9
61	98.4	98.3	99.0	100.7	100.7	101.4	104.3	104.2	105.0	127.1	127.1	127.9	128.4	128.4	129.2
62	134.6	134.5	134.5	137.0	136.9	136.9	140.6	140.5	140.4	163.5	163.5	163.5	164.8	164.8	164.8
63	134.6	134.5	134.5	137.0	137.0	136.9	140.7	140.6	140.6	163.7	163.7	163.7	165.1	165.1	165.1
64	134.6	134.6	134.5	137.1	137.1	137.0	140.8	140.7	140.7	164.0	164.0	164.0	165.4	165.4	165.4
65	134.7	134.6	134.6	137.2	137.1	137.1	140.9	140.8	140.8	164.3	164.3	164.3	165.7	165.7	165.7
66	134.7	134.7	134.6	137.3	137.2	137.2	141.0	141.0	140.9	164.5	164.5	164.5	166.0	166.0	166.0
67	134.7	134.7	134.6	137.4	137.3	137.2	141.1	141.1	141.0	164.8	164.8	164.8	166.2	166.2	166.2
68	134.8	134.7	134.7	137.4	137.4	137.3	141.2	141.2	141.1	165.0	165.0	165.0	166.5	166.5	166.5
69	134.8	134.8	134.7	137.5	137.5	137.4	141.4	141.3	141.2	165.3	165.3	165.3	166.8	166.8	166.8
70	134.9	134.8	134.8	137.6	137.5	137.5	141.5	141.4	141.4	165.5	165.5	165.5	167.0	167.0	167.0
71	134.9	134.9	134.8	137.7	137.6	137.6	141.6	141.5	141.5	165.8	165.8	165.8	167.3	167.3	167.3
72	135.0	134.9	134.9	137.8	137.7	137.7	141.7	141.7	141.6	166.0	166.0	166.0	167.6	167.6	167.6
73	135.0	135.0	134.9	137.8	137.8	137.7	141.8	141.8	141.7	166.2	166.2	166.2	167.8	167.8	167.8
74	135.0	135.0	135.0	137.9	137.9	137.8	141.9	141.9	141.8	166.5	166.5	166.5	168.1	168.1	168.1
75	135.1	135.0	135.0	138.0	138.0	137.9	142.1	142.0	142.0	166.7	166.7	166.7	168.4	168.4	168.3
76	135.1	135.1	135.0	138.1	138.0	138.0	142.2	142.1	142.1	166.9	166.9	166.8	168.6	168.5	168.4
77	135.2	135.1	135.1	138.2	138.1	138.1	142.3	142.2	142.2	167.0	166.9	166.9	168.7	168.6	168.5
78	135.2	135.2	135.1	138.3	138.2	138.2	142.4	142.3	142.3	167.1	167.0	166.9	168.8	168.7	168.7
79	135.3	135.2	135.2	138.4	138.3	138.3	142.6	142.5	142.5	167.2	167.1	167.0	168.9	168.8	168.8
80	135.3	135.3	135.2	138.4	138.4	138.4	142.7	142.6	142.6	167.3	167.2	167.1	169.0	168.9	168.9
81	135.4	135.3	135.3	138.5	138.5	138.4	142.8	142.8	142.7	167.4	167.3	167.2	169.2	169.1	169.0
82	135.4	135.4	135.3	138.6	138.6	138.5	142.9	142.9	142.8	167.5	167.4	167.3	169.3	169.2	169.1
83	135.5	135.4	135.4	138.7	138.7	138.6	143.1	143.0	143.0	167.6	167.5	167.4	169.4	169.3	169.2
84	135.5	135.5	135.5	138.8	138.8	138.7	143.2	143.1	143.1	167.7	167.6	167.5	169.5	169.4	169.4
85	135.6	135.5	135.5	138.9	138.9	138.8	143.3	143.3	143.2	167.8	167.7	167.6	169.6	169.5	169.5
86	135.6	135.6	135.6	139.0	138.9	138.9	143.4	143.4	143.3	167.9	167.8	167.7	169.7	169.6	169.6
87	135.7	135.7	135.6	139.1	139.0	139.0	143.5	143.5	143.5	168.0	167.9	167.8	169.8	169.7	169.7
88	135.7	135.7	135.7	139.2	139.1	139.1	143.7	143.6	143.6	168.1	168.0	167.9	170.0	169.9	169.9
89	135.8	135.8	135.7	139.3	139.2	139.2	143.8	143.8	143.7	168.2	168.1	168.0	170.1	170.0	170.0
90	135.9	135.8	135.8	139.4	139.3	139.3	143.9	143.9	143.9	168.3	168.2	168.2	170.3	170.2	170.1
91	135.9	135.9	135.8	139.5	139.4	139.4	144.1	144.0	144.0	168.4	168.3	168.3	170.4	170.3	170.3
92	136.0	135.9	135.9	139.5	139.5	139.5	144.2	144.1	144.1	168.5	168.4	168.4	170.5	170.4	170.4
93	136.0	136.0	135.9	139.6	139.6	139.5	144.3	144.3	144.2	168.6	168.5	168.5	170.7	170.6	170.5
94	136.1	136.0	136.0	139.7	139.7	139.6	144.4	144.4	144.4	168.7	168.7	168.6	170.8	170.7	170.7
95	136.1	136.1	136.0	139.8	139.8	139.7	144.6	144.5	144.5	168.9	168.8	168.7	170.9	170.8	170.8
96	136.2	136.1	136.1	139.9	139.9	139.8	144.7	144.7	144.6	169.0	168.9	168.8	171.1	171.0	170.9
97	136.2	136.2	136.2	140.0	140.0	139.9	144.8	144.8	144.8	169.1	169.0	169.0	171.2	171.1	171.1
98	136.3	136.3	136.2	140.1	140.1	140.0	145.0	144.9	144.9	169.2	169.1	169.1	171.4	171.3	171.2
99	136.3	136.3	136.3	140.2	140.1	140.1	145.1	145.0	145.0	169.3	169.3	169.2	171.5	171.4	171.4
100	136.4	136.4	136.3	140.3	140.2	140.2	145.2	145.2	145.1	169.4	169.4	169.3	171.6	171.5	171.5
101	136.5	136.4	136.4	140.4	140.3	140.3	145.3	145.3	145.3	169.5	169.5	169.4	171.8	171.7	171.6
102	136.5	136.5	136.4	140.5	140.4	140.4	145.5	145.4	145.4	169.7	169.6	169.6	171.9	171.8	171.8
103	136.6	136.5	136.5	140.6	140.5	140.5	145.6	145.6	145.5	169.8	169.7	169.7	172.1	172.0	171.9
104	136.6	136.6	136.5	140.7	140.6	140.6	145.7	145.7	145.7	169.9	169.9	169.8	172.2	172.1	172.1
105	136.7	136.6	136.6	140.8	140.7	140.7	145.9	145.8	145.8	170.0	170.0	169.9	172.3	172.2	172.2
106	136.7	136.7	136.7	140.8	140.8	140.8	146.0	145.9	145.9	170.2	170.1	170.0	172.5	172.4	172.4
107	136.8	136.8	136.7	140.9	140.9	140.9	146.1	146.1	146.0	170.3	170.2	170.2	172.6	172.5	172.5
108	136.8	136.8	136.8	141.0	141.0	141.0	146.2	146.2	146.2	170.4	170.4	170.3	172.8	172.7	172.7
109	136.9	136.9	136.8	141.1	141.1	141.1	146.3	146.3	146.3	170.5	170.5	170.4	172.9	172.8	172.8
110	137.0	136.9	136.9	141.2	141.2	141.2	146.5	146.5	146.4	170.7	170.6	170.6	173.1	173.0	173.0
111	137.0	137.0	136.9	141.3	141.3	141.3	146.6	146.6	146.6	170.8	170.7	170.7	173.2	173.1	173.1
112	137.1	137.0	137.0	141.4	141.4	141.3	146.8	146.7	146.7	170.9	170.9	170.8	173.4	173.3	173.3
113	137.1	137.1	137.1	141.5	141.5	141.4	146.9	146.8	146.8	171.1	171.0	170.9	173.5	173.4	173.4
114	137.2	137.1	137.1	141.6	141.6	141.6	147.0	147.0	147.0	171.2	171.1	171.1	173.7	173.6	173.6
115	137.2	137.2	137.2	141.7	141.7	141.7	147.1	147.1	147.1	171.3	171.3	171.2	173.8	173.8	173.7
116	137.3	137.3	137.3	141.8	141.8	141.8	147.3	147.3	147.3	171.4	171.4	171.3	174.0	173.9	173.9
117	137.4	137.4	137.4	142.0	142.0	142.0	147.5	147.5	147.5	171.6	171.5	171.5	174.1	174.1	174.0
118	137.5	137.5	137.5	142.1	142.1	142.1	147.6	147.6	147.6	171.7	171.6	171.6	174.3	174.2	174.2
119	137.6	137.6	137.6	142.2	142.2	142.2	147.8	147.8	147.8	171.8	171.8	171.7	174.4	174.4	174.3
120	137.7	137.7	137.7	142.4	142.4	142.4	148.0	148.0	148.0	172.0	171.9	171.9	174.6	174.5	174.5

TABLE A-1
(Continued)

	2000 Hz			2500 Hz			3500 Hz			5000 Hz			10000 Hz		
Mile	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep
1	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3	66.3
2	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5	72.5
3	76.2	136.7	76.2	76.2	136.8	76.2	76.2	136.9	76.2	76.2	136.9	76.2	76.3	137.0	76.3
4	137.6	137.6	78.8	137.7	137.7	78.9	137.8	137.7	78.9	137.8	137.8	78.9	137.9	137.8	79.0
5	138.5	138.5	80.9	138.6	138.6	81.0	138.7	138.7	81.0	138.8	138.7	81.1	138.8	138.8	81.1
6	139.4	139.4	82.7	139.5	139.5	82.7	139.6	139.6	82.8	139.7	139.7	82.8	139.7	139.7	82.9
7	140.3	140.3	140.3	140.5	140.4	140.4	140.6	140.5	140.5	140.6	140.6	140.6	140.7	140.7	140.6
8	141.2	141.2	141.2	141.4	141.3	141.3	141.5	141.5	141.4	141.6	141.5	141.5	141.6	141.6	141.6
9	142.1	142.1	142.1	142.2	142.2	142.2	142.4	142.3	142.3	142.4	142.4	142.4	142.5	142.5	142.5
10	142.9	142.9	142.9	143.1	143.1	143.0	143.2	143.2	143.2	143.3	143.3	143.3	143.4	143.4	143.3
11	143.7	143.7	143.7	143.9	143.9	143.9	144.0	144.0	144.0	144.1	144.1	144.1	144.2	144.2	144.2
12	144.5	144.5	144.5	144.7	144.7	144.6	144.8	144.8	144.8	144.9	144.9	144.9	145.0	145.0	145.0
13	145.2	145.2	145.2	145.4	145.4	145.4	145.6	145.6	145.6	145.7	145.7	145.7	145.8	145.8	145.7
14	145.9	145.9	145.9	146.1	146.1	146.1	146.3	146.3	146.3	146.4	146.4	146.4	146.5	146.5	146.5
15	146.6	146.6	146.6	146.8	146.8	146.8	147.0	147.0	147.0	147.1	147.1	147.1	147.2	147.2	147.2
16	147.3	147.3	147.3	147.5	147.5	147.5	147.7	147.7	147.7	147.8	147.8	147.8	147.9	147.9	147.9
17	147.9	147.9	147.9	148.1	148.1	148.1	148.3	148.3	148.3	148.5	148.5	148.5	148.6	148.6	148.6
18	148.5	148.5	148.5	148.7	148.7	148.7	149.0	149.0	149.0	149.1	149.1	149.1	149.2	149.2	149.2
19	149.1	149.1	149.1	149.3	149.3	149.3	149.6	149.6	149.6	149.7	149.7	149.7	149.8	149.8	149.8
20	149.7	149.7	149.6	149.9	149.9	149.9	150.2	150.2	150.2	150.3	150.3	150.3	150.4	150.4	150.4
21	150.2	150.2	150.2	150.5	150.5	150.5	150.7	150.7	150.7	150.9	150.9	150.9	151.0	151.0	151.0
22	150.7	150.7	150.7	151.0	151.0	151.0	151.3	151.3	151.3	151.5	151.5	151.5	151.6	151.6	151.6
23	151.3	151.3	151.3	151.6	151.6	151.6	151.9	151.8	151.8	152.0	152.0	152.0	152.2	152.2	152.2
24	151.8	151.8	151.8	152.1	152.1	152.1	152.4	152.4	152.4	152.6	152.6	152.6	152.7	152.7	152.7
25	152.3	152.3	152.3	152.6	152.6	152.6	152.9	152.9	152.9	153.1	153.1	153.1	153.2	153.2	153.2
26	152.7	152.7	152.7	153.1	153.1	153.1	153.4	153.4	153.4	153.6	153.6	153.6	153.8	153.8	153.7
27	117.1	117.1	117.8	117.4	117.4	118.2	117.7	117.7	118.5	117.9	117.9	118.7	118.1	118.1	118.9
28	117.5	117.5	118.3	117.9	117.9	118.7	118.2	118.2	119.0	118.4	118.4	119.2	118.6	118.6	119.4
29	118.0	118.0	118.8	118.3	118.3	119.1	118.7	118.7	119.5	118.9	118.9	119.7	119.1	119.1	119.9
30	118.4	118.4	119.2	118.8	118.8	119.6	119.2	119.2	120.0	119.4	119.4	120.2	119.6	119.6	120.4
31	118.8	118.8	119.6	119.2	119.2	120.0	119.6	119.6	120.2	119.9	119.9	120.7	120.0	120.0	120.8
32	119.3	119.3	120.1	119.7	119.7	120.5	120.1	120.1	120.9	120.3	120.3	121.1	120.5	120.5	121.3
33	119.7	119.7	120.5	120.1	120.1	120.9	120.5	120.5	121.3	120.8	120.8	121.6	121.0	121.0	121.7
34	120.1	120.1	120.9	120.5	120.5	121.3	121.0	121.0	121.7	121.2	121.2	122.0	121.4	121.4	122.2
35	156.7	156.7	121.3	157.1	157.1	121.7	157.5	157.5	122.2	157.8	157.8	122.4	158.0	158.0	122.6
36	157.1	157.1	157.1	157.5	157.5	157.5	158.0	158.0	158.0	158.2	158.2	158.2	158.4	158.4	158.4
37	157.5	157.5	157.5	157.9	157.9	157.9	158.4	158.4	158.4	158.7	158.7	158.7	158.9	158.9	158.9
38	157.8	157.8	157.8	158.3	158.3	158.3	158.8	158.8	158.8	159.1	159.1	159.1	159.3	159.3	159.3
39	158.2	158.2	158.2	158.7	158.7	158.7	159.2	159.2	159.2	159.5	159.5	159.5	159.7	159.7	159.7
40	158.6	158.6	158.6	159.1	159.1	159.1	159.6	159.6	159.6	159.9	159.9	159.9	160.1	160.1	160.1
41	159.0	159.0	159.0	159.5	159.5	159.5	160.0	160.0	160.0	160.3	160.3	160.3	160.5	160.5	160.5
42	159.3	159.3	159.3	159.9	159.9	159.9	160.4	160.4	160.4	160.7	160.7	160.7	160.9	160.9	160.9
43	159.7	159.7	159.7	160.2	160.2	160.2	160.8	160.8	160.8	161.1	161.1	161.1	161.3	161.3	161.3
44	160.0	160.0	160.0	160.6	160.6	160.6	161.1	161.1	161.1	161.5	161.5	161.5	161.7	161.7	161.7
45	160.4	160.4	160.4	161.0	161.0	161.0	161.5	161.5	161.5	161.9	161.9	161.9	162.1	162.1	162.1
46	160.7	160.7	160.7	161.3	161.3	161.3	161.9	161.9	161.9	162.2	162.2	162.2	162.5	162.5	162.5
47	161.1	161.1	161.1	161.7	161.7	161.7	162.3	162.3	162.3	162.6	162.6	162.6	162.9	162.9	162.9
48	161.4	161.4	161.4	162.0	162.0	162.0	162.6	162.6	162.6	163.0	163.0	163.0	163.3	163.3	163.3
49	161.8	161.8	161.8	162.4	162.4	162.4	163.0	163.0	163.0	163.4	163.4	163.4	163.6	163.6	163.6
50	162.1	162.1	162.1	162.7	162.7	162.7	163.3	163.3	163.3	163.7	163.7	163.7	164.0	164.0	164.0
51	162.4	162.4	162.4	163.1	163.1	163.1	163.7	163.7	163.7	164.1	164.1	164.1	164.4	164.4	164.4

TABLE A-1
(Continued)

52	162.7	162.7	162.7	163.4	163.4	163.4	164.1	164.0	164.0	164.4	164.4	164.4	164.7	164.7	164.7
53	126.9	126.9	127.7	127.6	127.6	128.4	128.2	128.2	129.0	128.6	128.6	129.4	128.9	128.9	129.7
54	127.2	127.2	128.0	127.9	127.9	128.7	128.6	128.6	129.4	129.0	129.0	129.8	129.3	129.3	130.1
55	127.5	127.5	128.3	128.2	128.2	129.0	128.9	128.9	129.7	129.3	129.3	130.1	129.6	129.6	130.4
56	127.9	127.9	128.7	128.6	128.6	129.4	129.3	129.3	130.1	129.7	129.7	130.5	130.0	130.0	130.8
57	128.2	128.2	129.0	128.9	128.9	129.7	129.6	129.6	130.4	130.0	130.0	130.8	130.4	130.3	131.1
58	128.5	128.5	129.3	129.2	129.2	130.0	129.9	129.9	130.7	130.4	130.4	131.2	130.7	130.7	131.5
59	128.8	128.8	129.9	129.5	129.5	130.3	130.3	130.3	131.1	130.7	130.7	131.5	131.0	131.0	131.8
60	129.1	129.1	129.9	129.8	129.8	130.6	130.6	130.6	131.4	131.0	131.0	131.8	131.4	131.4	132.2
61	129.4	129.4	130.2	130.2	130.2	130.9	130.9	130.9	131.7	131.4	131.4	132.2	131.7	131.7	132.5
62	165.9	165.9	165.9	166.6	166.6	166.6	167.4	167.4	167.4	167.9	167.9	167.9	168.2	168.2	168.2
63	166.2	166.2	166.2	166.9	166.9	166.9	167.7	167.7	167.7	168.2	168.2	168.2	168.6	168.6	168.6
64	166.4	166.4	166.4	167.2	167.2	167.2	168.0	168.0	168.0	168.5	168.5	168.5	168.9	168.9	168.9
65	166.7	166.7	166.7	167.6	167.6	167.6	168.4	168.4	168.4	168.8	168.8	168.8	169.2	169.2	169.2
66	167.0	167.0	167.0	167.9	167.9	167.9	168.7	168.7	168.7	169.2	169.2	169.2	169.6	169.6	169.6
67	167.3	167.3	167.3	168.2	168.2	168.2	169.0	169.0	169.0	169.5	169.5	169.5	169.9	169.9	169.9
68	167.6	167.6	167.6	168.5	168.5	168.5	169.3	169.3	169.3	169.8	169.8	169.8	170.2	170.2	170.2
69	167.9	167.9	167.9	168.8	168.8	168.8	169.6	169.6	169.6	170.1	170.1	170.1	170.5	170.5	170.5
70	168.2	168.2	168.2	169.1	169.0	169.0	169.9	169.9	169.9	170.4	170.4	170.4	170.8	170.8	170.8
71	168.5	168.5	168.5	169.3	169.3	169.3	170.2	170.2	170.2	170.8	170.8	170.8	171.2	171.2	171.2
72	168.7	168.7	168.7	169.6	169.6	169.6	170.5	170.5	170.5	171.1	171.1	171.1	171.5	171.5	171.5
73	169.0	169.0	169.0	169.9	169.9	169.9	170.8	170.8	170.8	171.4	171.4	171.4	171.8	171.8	171.8
74	169.3	169.3	169.3	170.2	170.2	170.2	171.1	171.1	171.1	171.7	171.7	171.7	172.1	172.1	172.1
75	169.6	169.6	169.6	170.5	170.5	170.5	171.4	171.4	171.4	172.0	172.0	172.0	172.4	172.4	172.4
76	169.8	169.8	169.7	170.8	170.7	170.6	171.7	171.7	171.6	172.3	172.2	172.1	172.7	172.6	172.6
77	170.0	169.9	169.8	170.9	170.8	170.8	171.9	171.8	171.7	172.5	172.4	172.3	172.9	172.8	172.7
78	170.1	170.0	169.9	171.1	171.0	170.9	172.0	171.9	171.8	172.6	172.5	172.4	173.1	173.0	172.9
79	170.2	170.1	170.0	171.2	171.1	171.0	172.2	172.1	172.0	172.8	172.7	172.6	173.2	173.1	173.0
80	170.3	170.3	170.2	171.3	171.3	171.2	172.3	172.3	172.2	173.0	172.9	172.8	173.4	173.3	173.2
81	170.5	170.4	170.3	171.5	171.4	171.3	172.5	172.4	172.3	173.1	173.0	172.9	173.6	173.5	173.4
82	170.6	170.5	170.4	171.6	171.5	171.4	172.7	172.6	172.5	173.3	173.2	173.1	173.7	173.6	173.5
83	170.7	170.7	170.6	171.8	171.7	171.6	172.8	172.7	172.6	173.4	173.3	173.2	173.8	173.7	173.6
84	170.9	170.8	170.7	171.9	171.8	171.8	173.0	172.9	172.8	173.6	173.5	173.4	174.1	174.0	173.9
85	171.0	170.9	170.9	172.1	172.0	171.9	173.1	173.0	172.9	173.8	173.7	173.6	174.3	174.2	174.1
86	171.2	171.1	171.0	172.2	172.2	172.1	173.3	173.2	173.1	173.9	173.8	173.7	174.4	174.3	174.2
87	171.3	171.2	171.1	172.3	172.3	172.2	173.4	173.3	173.2	174.1	174.0	173.9	174.6	174.5	174.4
88	171.4	171.4	171.3	172.5	172.5	172.4	173.6	173.5	173.4	174.3	174.2	174.1	174.8	174.7	174.6
89	171.6	171.5	171.4	172.7	172.6	172.5	173.8	173.7	173.6	174.5	174.4	174.3	175.0	174.9	174.8
90	171.7	171.7	171.6	172.9	172.8	172.7	174.0	173.9	173.8	174.6	174.5	174.4	175.1	175.0	174.9
91	171.9	171.8	171.7	173.0	172.9	172.8	174.1	174.0	173.9	174.8	174.7	174.6	175.2	175.1	175.0
92	172.0	172.0	171.9	173.2	173.1	173.0	174.3	174.2	174.1	175.0	174.9	174.8	175.3	175.2	175.1
93	172.2	172.1	172.0	173.3	173.3	173.2	174.5	174.4	174.3	175.1	175.0	174.9	175.4	175.3	175.2
94	172.3	172.3	172.2	173.5	173.4	173.3	174.7	174.6	174.5	175.2	175.1	175.0	175.5	175.4	175.3
95	172.5	172.4	172.3	173.7	173.6	173.5	174.8	174.7	174.6	175.3	175.2	175.1	175.6	175.5	175.4
96	172.6	172.6	172.5	173.8	173.8	173.7	175.0	174.9	174.8	175.4	175.3	175.2	175.7	175.6	175.5
97	172.8	172.7	172.6	174.0	173.9	173.8	175.2	175.1	175.0	175.5	175.4	175.3	175.8	175.7	175.6
98	172.9	172.9	172.8	174.2	174.1	174.0	175.4	175.3	175.2	175.6	175.5	175.4	175.9	175.8	175.7
99	173.1	173.0	172.9	174.3	174.3	174.2	175.6	175.5	175.4	175.8	175.7	175.6	176.0	175.9	175.8
100	173.3	173.2	173.1	174.5	174.4	174.3	175.7	175.6	175.5	175.9	175.8	175.7	176.1	176.0	175.9
101	173.4	173.3	173.2	174.7	174.6	174.5	175.9	175.8	175.7	176.0	175.9	175.8	176.2	176.1	176.0
102	173.6	173.5	173.4	174.8	174.8	174.7	176.1	176.0	175.9	176.2	176.1	176.0	176.3	176.2	176.1
103	173.7	173.7	173.6	175.0	174.9	174.8	176.3	176.2	176.1	176.4	176.3	176.2	176.5	176.4	176.3
104	173.9	173.8	173.7	175.2	175.1	175.0	176.5	176.4	176.3	176.6	176.5	176.4	176.7	176.6	176.5
105	174.0	174.0	173.9	175.4	175.3	175.2	176.7	176.6	176.5	176.8	176.7	176.6	176.9	176.8	176.7
106	174.2	174.1	174.0	175.6	175.5	175.4	176.9	176.8	176.7	177.0	176.9	176.8	177.1	177.0	176.9
107	174.4	174.3	174.2	175.7	175.6	175.5	177.1	177.0	176.9	177.2	177.1	177.0	177.3	177.2	177.1
108	174.5	174.5	174.4	175.9	175.8	175.7	177.3	177.2	177.1	177.4	177.3	177.2	177.5	177.4	177.3
109	174.7	174.6	174.5	176.1	176.0	175.9	177.5	177.4	177.3	177.6	177.5	177.4	177.7	177.6	177.5
110	174.9	174.8	174.7	176.2	176.2	176.1	177.6	177.5	177.4	177.8	177.7	177.6	177.9	177.8	177.7
111	175.0	175.0	174.9	176.4	176.3	176.2	177.8	177.7	177.6	177.9	177.8	177.7	178.0	177.9	177.8
112	175.2	175.1	175.0	176.6	176.5	176.4	178.0	177.9	177.8	178.1	178.0	177.9	178.2	178.1	178.0
113	175.4	175.3	175.2	176.8	176.7	176.6	178.2	178.1	178.0	178.3	178.2	178.1	178.4	178.3	178.2
114	175.5	175.5	175.4	176.9	176.9	176.8	178.4	178.3	178.2	178.5	178.4	178.3	178.6	178.5	178.4
115	175.7	175.6	175.5	177.1	177.0	176.9	178.6	178.5	178.4	178.7	178.6	178.5	178.8	178.7	178.6
116	175.9	175.8	175.7	177.3	177.2	177.1	178.8	178.7	178.6	178.9	178.8	178.7	179.0	178.9	178.8
117	176.0	176.0	175.9	177.5	177.4	177.3	179.0	178.9	178.8	179.1	179.0	178.9	179.2	179.1	179.0
118	176.2	176.1	176.0	177.7	177.6	177.5	179.2	179.1	179.0	179.3	179.2	179.1	179.4	179.3	179.2
119	176.4	176.3	176.2	177.8	177.7	177.6	179.4	179.3	179.2	179.5	179.4	179.3	179.6	179.5	179.4
120	176.5	176.5	176.4	178.0	177.9	177.8	179.6	179.5	179.4	179.7	179.6	179.5	179.8	179.7	179.6
121	176.7	176.6	176.5	178.2	178.1	178.0	179.8	179.7	179.6	179.9	179.8	179.7	180.0	179.9	179.8
122	176.9	176.8	176.7	178.4	178.3	178.2	180.0	179.9	179.8	180.1	180.0	179.9	180.2	180.1	180.0
123	177.1	177.0	176.9	178.6	178.5	178.4	180.2	180.1	180.0	180.3	180.2	180.1	180.4	180.3	180.2
124	177.3	177.2	177.1	178.8	178.7	178.6	180.4	180.3	180.2	180.5	180.4	180.3	180.6	180.5	180.4
125	177.5	177.4	177.3	179.0	178.9	178.8	180.6	180.5	180.4	180.7	180.6	180.5	180.8	180.7	180.6
126	177.7	177.6	177.5	179.2	179.1	179.0	180.8	180.7	180.6	180.9	180.8	180.7	181.0	180.9	180.8
127	177.9	177.8	177.7	179.4	179.3	179.2	181.0	180.9	180.8	181.1	181.0	180.9	18		

TABLE A-2

ENVIRONMENT FILE = A123D ENV

SONIC LAYER DEPTH = 314 feet

NUMBER OF FREQUENCIES = 20

NUMBER OF ACTIVE SONOBUOYS = 3

NUMBER OF ACTIVE SONARS = 24

FREQUENCIES (Hz):

10 15 20 30 40 60 80 100 125 250 315 630 900 1250 1600 2000 2500 3500 5000 10000

AMBIENT NOISE (dB):

76 80 82 87 89 91 89 87 85 84 85 84 87 87 87 87 87 86 84 79

ACTIVE SONOBUOY DATA:

Type Range (nautical miles)

SSG47 2.00

SSG50 3.00

SSG62 3.00

ACTIVE SONAR DATA. (depth in feet, ranges in nautical miles)

Type	Dip/Tow Depth	DP Range						BB Range Limits				CZ Limits	
		12 knots		18 knots		24 knots		Inner	Outer	Inner	Outer	Inner	Outer
AGS13	30	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ARTIM	0	3.0	2.0	3.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
BGG3A	0	19.0	3.0	15.0	3.0	11.0	3.0	11.0	14.0	11.0	14.0	0.0	0.0
BULLN	0	4.0	2.0	3.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
BWOOD	0	2.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FENKM	0	2.0	2.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FOALT	0	2.0	2.0	2.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
MARET	0	3.0	2.0	2.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
NEWCN	0	7.0	2.0	4.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
OGS01	0	11.0	3.0	8.0	3.0	3.0	2.0	10.0	12.0	10.0	12.0	0.0	0.0
OGS3	0	8.0	3.0	4.0	3.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
OGS4	0	9.0	0.0	5.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PEGA2	0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SHRKF	0	2.0	2.0	2.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
SHRKT	0	3.0	2.0	3.0	2.0	2.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
SGG23	0	9.0	2.0	7.0	2.0	4.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
SGR26	0	12.0	3.0	12.0	3.0	10.0	3.0	24.0	30.0	24.0	30.0	0.0	0.0
SGS23	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SGS26	0	11.0	3.0	9.0	3.0	4.0	2.0	15.0	19.0	15.0	19.0	0.0	0.0
SGS35	250	3.0	1.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SGS33	0	12.0	3.0	12.0	3.0	12.0	3.0	22.0	28.0	22.0	28.0	0.0	0.0
SGS36	0	5.0	2.0	4.0	2.0	3.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
TAMR5	0	1.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TMR11	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE A-2
(Continued)

PROPAGATION LOSS DATA: (all values in dB)

Mile	10 Hz			15 Hz			20 Hz			30 Hz			40 Hz		
	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep
1	80.1	78.0	64.9	74.9	75.5	64.9	72.5	74.5	64.9	74.2	75.2	64.9	95.2	76.5	64.9
2	81.2	79.0	71.7	75.8	76.4	71.7	73.2	75.4	71.7	73.8	76.5	71.8	84.4	82.8	71.8
3	82.8	80.1	73.9	77.2	77.4	74.0	74.3	76.2	74.0	73.6	76.6	74.0	80.0	81.6	74.1
4	84.8	81.4	75.9	79.0	78.6	76.0	75.7	77.2	76.0	73.9	76.9	76.0	77.4	79.8	76.1
5	86.8	82.8	77.8	80.8	79.9	77.9	77.4	78.3	77.9	74.8	77.5	78.0	76.3	79.1	78.0
6	88.7	84.2	79.6	82.7	81.3	79.7	79.1	79.5	79.7	75.9	78.3	79.8	76.2	79.1	79.9
7	90.5	85.6	81.4	84.5	82.6	81.5	80.8	80.8	81.5	77.2	79.2	81.7	76.6	79.5	81.8
8	90.5	85.0	80.2	84.3	81.9	80.3	80.4	80.0	80.4	76.2	78.1	80.6	74.8	77.9	80.8
9	91.9	85.3	79.5	85.7	82.2	79.7	81.7	80.2	79.8	77.2	78.1	80.0	75.3	77.5	80.2
10	93.5	86.4	79.9	87.2	83.2	80.0	83.2	81.2	80.1	78.6	78.9	80.3	76.3	78.0	80.5
11	95.1	87.4	80.3	88.7	84.3	80.4	84.7	82.2	80.5	79.9	79.8	80.6	77.5	78.6	80.8
12	96.5	88.5	80.6	90.2	85.3	80.7	86.1	83.2	80.8	81.2	80.6	80.9	78.7	79.3	81.1
13	97.9	89.5	80.9	91.5	86.3	81.0	87.4	84.1	81.0	82.5	81.5	81.2	79.9	80.0	81.3
14	99.2	90.5	81.1	92.8	87.2	81.2	88.7	85.1	81.3	83.8	82.3	81.4	81.1	80.8	81.6
15	100.6	91.6	81.4	94.3	88.3	81.5	90.1	86.1	81.5	85.2	83.3	81.7	82.4	81.7	81.8
16	98.9	90.6	81.0	92.5	87.4	81.1	88.4	85.3	81.1	83.5	82.7	81.3	81.2	81.4	81.5
17	98.1	89.9	80.6	91.7	86.8	80.7	87.6	84.7	80.8	82.7	82.3	81.0	80.5	81.1	81.2
18	99.5	90.8	80.9	93.1	87.6	81.0	88.8	85.6	81.1	83.8	83.0	81.3	81.4	81.8	81.4
19	100.5	91.5	81.1	94.1	88.3	81.2	89.8	86.2	81.3	84.7	83.7	81.5	82.1	82.3	81.7
20	101.5	92.2	81.4	95.0	89.0	81.5	90.7	86.9	81.6	85.5	84.3	81.7	82.8	82.9	81.9
21	102.5	92.9	81.7	96.0	89.7	81.8	91.7	87.6	81.8	86.3	84.9	82.0	83.4	83.5	82.1
22	103.5	93.6	82.0	97.0	90.4	82.1	92.6	88.2	82.1	87.1	85.5	82.3	84.1	84.0	82.4
23	104.5	94.3	82.3	97.9	91.1	82.4	93.5	88.9	82.5	87.9	86.1	82.6	84.8	84.6	82.7
24	101.6	92.7	82.1	95.2	89.6	82.2	91.0	87.6	82.3	86.0	85.1	82.5	83.4	83.9	82.7
25	101.2	92.5	82.2	94.9	89.4	82.3	90.7	87.4	82.4	85.7	85.0	82.7	83.2	83.9	82.9
26	102.3	93.2	82.6	95.9	90.1	82.7	91.7	88.0	82.9	86.5	85.6	83.1	83.9	84.4	83.3
27	103.1	93.7	83.0	96.6	90.6	83.1	92.4	88.5	83.2	87.1	86.0	83.4	84.4	84.8	83.7
28	103.8	94.2	83.4	97.4	91.0	83.5	93.1	89.0	83.6	87.7	86.4	83.8	84.9	85.1	84.1
29	104.6	94.7	83.8	98.1	91.5	83.9	93.7	89.4	84.0	88.4	86.8	84.3	85.4	85.5	84.5
30	105.3	95.1	84.2	98.8	91.9	84.3	94.4	89.8	84.4	89.0	87.2	84.7	85.9	85.8	84.9
31	104.8	95.0	84.4	98.4	91.8	84.5	94.1	89.8	84.6	88.8	87.2	84.9	85.9	85.9	85.1
32	103.5	94.3	84.3	97.2	91.3	84.5	93.0	89.3	84.6	88.0	86.9	84.9	85.4	85.7	85.2
33	103.3	94.3	84.4	97.0	91.2	84.6	92.9	89.2	84.8	87.9	86.9	85.1	85.4	85.8	85.4
34	104.0	94.7	84.7	97.7	91.6	84.9	93.5	89.6	85.0	88.5	87.3	85.4	85.9	86.1	85.7
35	104.6	95.1	85.0	98.3	92.0	85.1	94.1	90.0	85.3	89.0	87.6	85.6	86.3	86.4	85.9
36	105.2	95.5	85.2	98.8	92.4	85.4	94.6	90.3	85.6	89.4	87.9	85.9	86.7	86.6	86.2
37	105.8	95.8	85.4	99.4	92.7	85.6	95.1	90.7	85.8	89.9	88.2	86.1	87.1	86.9	86.4
38	106.4	96.2	85.6	99.9	93.1	85.8	95.7	91.0	86.0	90.3	88.5	86.3	87.4	87.2	86.6
39	106.9	96.6	85.8	100.5	93.4	86.0	96.2	91.4	86.2	90.8	88.8	86.5	87.8	87.5	86.8
40	107.5	96.9	86.0	101.0	93.8	86.1	96.7	91.7	86.3	91.3	89.2	86.6	88.2	87.7	86.9
41	108.0	97.3	86.1	101.6	94.1	86.3	97.2	92.0	86.4	91.7	89.5	86.7	88.6	88.0	87.0
42	108.6	97.6	86.3	102.1	94.5	86.4	97.7	92.4	86.6	92.2	89.8	86.9	89.0	88.3	87.2
43	105.8	96.1	85.8	99.5	93.1	86.0	95.3	91.2	86.2	90.4	88.9	86.6	87.8	87.7	87.0
44	106.2	96.5	86.0	99.9	93.4	86.2	95.8	91.5	86.4	90.7	89.1	86.7	88.1	87.9	87.1
45	106.7	96.8	86.1	100.4	93.7	86.3	96.2	91.7	86.5	91.1	89.4	86.9	88.4	88.1	87.2
46	107.2	97.1	86.2	100.8	94.0	86.4	96.6	92.0	86.6	91.5	89.6	87.0	88.7	88.4	87.3
47	107.6	97.3	86.3	101.3	94.3	86.5	97.0	92.3	86.7	91.9	89.9	87.1	89.0	88.6	87.4
48	108.1	97.6	86.5	101.7	94.6	86.6	97.5	92.6	86.8	92.2	90.1	87.2	89.3	88.8	87.5
49	108.5	97.9	86.6	102.1	94.9	86.8	97.9	92.8	86.9	92.6	90.4	87.3	89.7	89.0	87.6
50	109.0	98.2	86.7	102.6	95.1	86.9	98.3	93.1	87.1	93.0	90.6	87.4	90.0	89.2	87.7
51	109.4	98.5	86.8	103.0	95.4	87.0	98.7	93.4	87.2	93.3	90.9	87.5	90.3	89.5	87.8
52	107.1	97.3	86.5	100.9	94.3	86.7	96.8	92.4	87.0	91.9	90.2	87.1	89.4	89.0	87.7
53	107.5	97.6	86.7	101.3	94.6	86.9	97.2	92.7	87.1	92.2	90.4	87.5	89.6	89.2	87.8
54	107.9	97.8	86.8	101.6	94.8	87.0	97.5	92.9	87.2	92.5	90.6	87.6	89.9	89.4	88.0
55	108.3	98.1	86.9	102.0	95.1	87.1	97.9	93.1	87.3	92.8	90.8	87.7	90.1	89.6	88.1
56	108.7	98.3	87.0	102.4	95.3	87.3	98.2	93.4	87.5	93.1	91.0	87.9	90.4	89.8	88.2
57	109.0	98.6	87.2	102.7	95.5	87.4	98.6	93.6	87.6	93.4	91.2	88.0	90.7	90.0	88.3
58	109.4	98.8	87.3	103.1	95.8	87.5	98.9	93.8	87.7	93.7	91.4	88.1	90.9	90.1	88.5
59	109.9	99.0	87.5	103.5	96.0	87.7	99.3	94.0	87.9	94.1	91.5	88.2	91.2	90.3	88.6
60	107.8	98.1	87.3	101.7	95.1	87.6	97.7	93.3	87.8	92.9	91.1	88.2	90.5	90.0	88.5
61	106.2	96.3	87.4	102.1	95.4	87.6	98.0	93.5	87.8	93.2	91.3	88.3	90.7	90.2	88.7

REPRODUCED AT GOVERNMENT EXPENSE

TABLE A-2
(Continued)

62	108.5	98.5	87.5	102.4	95.6	87.7	98.3	93.7	88.0	93.5	91.5	88.4	90.5	90.4	88.6
63	108.9	98.7	87.6	102.7	95.8	87.9	98.6	93.9	88.1	93.7	91.7	88.6	91.2	90.5	89.0
64	109.2	98.9	87.8	103.0	96.0	88.0	98.9	94.1	88.2	94.0	91.8	88.7	91.4	90.7	89.1
65	109.5	99.1	87.9	103.3	96.2	88.1	99.2	94.3	88.4	94.3	92.0	88.8	91.6	90.8	89.2
66	109.9	99.3	88.0	103.6	96.4	88.3	99.5	94.5	88.5	94.5	92.2	89.0	91.8	91.0	89.4
67	110.2	99.6	88.2	104.0	96.6	88.4	99.8	94.7	88.6	94.8	92.4	89.1	92.1	91.2	89.5
68	110.5	99.8	88.3	104.3	96.8	88.5	100.1	94.9	88.8	95.1	92.6	89.2	92.3	91.3	89.6
69	109.9	98.9	88.1	102.8	96.1	88.4	98.8	94.2	88.6	94.1	92.2	89.2	91.7	91.1	89.6
70	109.2	99.1	88.2	103.1	96.2	88.5	99.1	94.4	88.8	94.4	92.3	89.3	91.9	91.3	89.7
71	109.5	99.3	88.3	103.4	96.4	88.6	99.4	94.6	88.9	94.6	92.5	89.4	92.1	91.4	89.8
72	109.8	99.5	88.4	103.6	96.6	88.7	99.6	94.8	89.0	94.8	92.6	89.5	92.3	91.5	89.9
73	110.0	99.7	88.5	103.9	96.8	88.8	99.9	94.9	89.1	95.1	92.8	89.6	92.5	91.7	90.0
74	110.3	99.9	88.6	104.2	97.0	88.9	100.2	95.1	89.2	95.3	92.9	89.7	92.7	91.8	90.1
75	110.6	100.1	88.7	104.5	97.1	89.0	100.4	95.3	89.3	95.5	93.1	89.8	92.9	92.0	90.2
76	110.9	100.2	88.8	104.7	97.3	89.1	100.7	95.5	89.4	95.8	93.3	89.9	93.1	92.1	90.3
77	109.5	99.9	88.8	103.5	97.1	89.1	99.6	95.3	89.4	95.0	93.2	89.9	92.7	92.1	90.4
78	109.7	99.7	88.7	103.7	96.9	89.1	99.8	95.1	89.3	95.2	93.1	89.9	92.9	92.1	90.4
79	110.0	99.9	88.8	104.0	97.0	89.1	100.1	95.3	89.4	95.4	93.2	90.0	93.0	92.2	90.5
80	110.3	100.0	88.9	104.2	97.2	89.2	100.3	95.4	89.5	95.6	93.4	90.1	93.2	92.3	90.5
81	110.5	100.2	89.0	104.5	97.4	89.3	100.5	95.6	89.6	95.8	93.5	90.1	93.4	92.4	90.6
82	110.8	100.4	89.1	104.7	97.5	89.4	100.8	95.7	89.7	96.0	93.6	90.2	93.6	92.6	90.7
83	111.0	100.5	89.2	105.0	97.7	89.5	101.0	95.9	89.7	96.2	93.8	90.3	93.7	92.7	90.8
84	111.3	100.7	89.3	105.2	97.8	89.5	101.2	96.0	89.8	96.4	93.9	90.4	93.9	92.8	90.8
85	111.6	100.8	89.3	105.4	98.0	89.6	101.5	96.2	89.9	96.6	94.0	90.4	94.1	92.9	90.9
86	110.3	100.2	89.1	104.3	97.5	89.5	100.5	95.7	89.8	96.0	93.8	90.4	93.7	92.8	90.9
87	110.5	100.4	89.2	104.6	97.6	89.6	100.7	95.9	89.9	96.2	93.9	90.5	93.9	92.9	91.0
88	110.8	100.5	89.3	104.8	97.7	89.6	100.9	96.0	89.9	96.4	94.0	90.5	94.1	93.0	91.0
89	111.0	100.7	89.4	105.0	97.9	89.7	101.2	96.1	90.0	96.6	94.1	90.6	94.2	93.1	91.1
90	111.2	100.8	89.5	105.2	98.0	89.8	101.4	96.3	90.1	96.8	94.3	90.7	94.4	93.3	91.2
91	111.5	101.0	89.5	105.5	98.2	89.9	101.6	96.4	90.2	96.9	94.4	90.7	94.5	93.4	91.2
92	111.7	101.1	89.6	105.7	98.3	89.9	101.8	96.5	90.2	97.1	94.5	90.8	94.7	93.5	91.3
93	111.9	101.3	89.7	105.9	98.4	90.0	102.0	96.7	90.3	97.3	94.6	90.9	94.8	93.6	91.4
94	112.1	101.0	89.7	106.1	98.3	90.0	102.2	96.6	90.3	97.5	94.6	90.9	95.0	93.6	91.4
95	111.0	100.8	89.6	105.1	98.1	90.0	101.4	96.4	90.3	97.0	94.5	90.9	94.7	93.6	91.3
96	111.2	101.0	89.7	105.3	98.3	90.1	101.6	96.6	90.4	97.1	94.7	91.0	94.9	93.7	91.6
97	111.4	101.1	89.8	105.5	98.4	90.2	101.7	96.7	90.5	97.3	94.8	91.1	95.0	93.8	91.6
98	111.6	101.2	89.9	105.7	98.5	90.2	101.9	96.8	90.6	97.5	94.9	91.2	95.2	93.9	91.7
99	111.9	101.4	90.0	105.9	98.6	90.3	102.1	96.9	90.6	97.6	95.0	91.3	95.3	94.0	91.8
100	112.1	101.5	90.0	106.1	98.8	90.4	102.3	97.1	90.7	97.8	95.1	91.3	95.4	94.1	91.9
101	112.3	101.7	90.1	106.3	98.9	90.5	102.5	97.2	90.8	97.9	95.2	91.4	95.6	94.2	91.9
102	112.5	101.8	90.2	106.5	99.0	90.5	102.7	97.3	90.9	98.1	95.3	91.5	95.7	94.3	92.0
103	111.5	101.3	90.1	105.7	98.6	90.5	102.0	97.0	90.8	97.7	95.2	91.5	95.5	94.3	92.1
104	111.7	101.4	90.2	105.9	98.8	90.6	102.1	97.1	90.9	97.8	95.3	91.6	95.6	94.4	92.1
105	111.9	101.5	90.2	106.0	98.9	90.6	102.3	97.2	91.0	98.0	95.4	91.7	95.8	94.5	92.2
106	112.1	101.7	90.3	106.2	99.0	90.7	102.5	97.3	91.1	98.1	95.5	91.7	95.9	94.6	92.3
107	112.2	101.8	90.4	106.4	99.1	90.8	102.7	97.5	91.1	98.3	95.6	91.8	96.0	94.7	92.4
108	112.4	101.9	90.5	106.6	99.2	90.8	102.8	97.6	91.2	98.4	95.7	91.9	96.2	94.8	92.4
109	112.6	102.0	90.5	106.8	99.3	90.9	103.0	97.7	91.3	98.6	95.8	91.9	96.3	94.9	92.5
110	112.8	102.2	90.6	106.9	99.5	91.0	103.2	97.8	91.3	98.7	95.9	92.0	96.4	94.9	92.6
111	113.0	102.3	90.6	107.1	99.6	91.0	103.3	97.9	91.4	98.9	96.0	92.1	96.5	95.0	92.6
112	112.1	101.8	90.6	106.4	99.2	91.0	102.7	97.6	91.4	98.5	95.9	92.1	96.4	95.0	92.7
113	112.3	102.0	90.6	106.5	99.3	91.1	102.9	97.7	91.4	98.6	96.0	92.1	96.5	95.1	92.7
114	112.5	102.1	90.7	106.7	99.4	91.1	103.0	97.8	91.5	98.8	96.1	92.2	96.6	95.2	92.8
115	112.6	102.2	90.8	106.9	99.6	91.2	103.2	97.9	91.6	98.9	96.1	92.2	96.7	95.3	92.8
116	112.8	102.3	90.8	107.0	99.7	91.2	103.3	98.0	91.6	99.0	96.2	92.3	96.9	95.4	92.9
117	113.0	102.4	90.9	107.2	99.8	91.3	103.5	98.1	91.7	99.2	96.3	92.4	97.0	95.4	92.9
118	113.2	102.5	90.9	107.4	99.9	91.3	103.7	98.2	91.7	99.3	96.4	92.4	97.1	95.5	93.0
119	113.3	102.6	91.0	107.5	100.0	91.4	103.8	98.3	91.8	99.5	96.5	92.5	97.2	95.6	93.1
120	112.5	102.2	90.9	106.8	99.7	91.4	103.3	98.1	91.8	99.2	96.4	92.5	97.1	95.6	93.1

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TABLE A-2
(Continued)

Mile	60 Hz			80 Hz			100 Hz			125 Hz			150 Hz		
	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep
1	74.2	66.8	64.9	71.3	64.1	64.9	70.5	63.3	64.8	69.5	63.1	64.8	68.1	62.7	64.8
2	81.2	73.7	71.8	75.9	71.7	71.8	73.7	70.7	71.8	74.3	70.3	71.8	72.1	69.3	71.8
3	86.5	79.5	74.1	77.5	78.6	74.2	78.2	78.3	74.2	77.3	77.3	74.2	74.7	74.7	74.4
4	87.9	82.2	76.2	79.5	79.5	76.3	79.5	79.9	76.3	79.2	79.2	76.4	76.8	76.8	76.7
5	87.2	84.0	78.2	82.1	80.6	78.3	80.7	80.9	78.4	80.7	80.7	78.5	78.6	78.6	78.9
6	84.7	83.9	80.1	83.8	81.9	80.3	81.9	81.8	80.4	81.8	81.8	80.6	80.2	80.2	81.3
7	82.3	83.2	82.0	84.3	83.0	82.2	82.9	82.6	82.5	82.7	82.7	82.7	81.5	81.5	83.8
8	78.3	80.8	81.2	82.3	82.1	81.6	81.9	81.8	82.0	81.9	82.3	82.5	82.6	82.6	84.7
9	77.1	79.5	80.6	81.3	81.5	81.1	81.8	81.4	81.5	82.0	82.0	82.1	83.2	83.2	84.7
10	76.8	79.3	80.9	80.7	81.4	81.3	81.9	81.6	81.7	82.3	82.1	82.2	83.7	83.6	84.6
11	77.0	79.3	81.2	80.3	81.3	81.6	82.0	81.8	81.9	82.5	82.3	82.4	84.0	83.8	84.6
12	77.4	79.4	81.4	80.1	81.2	81.8	82.1	82.0	82.1	82.7	82.4	82.5	84.3	84.0	84.5
13	78.1	79.7	81.6	80.1	81.2	81.9	82.1	82.1	82.2	82.8	82.5	82.6	84.4	84.0	84.5
14	78.9	80.1	81.8	80.2	81.3	82.1	82.3	82.2	82.4	83.0	82.5	82.7	84.5	84.0	84.4
15	79.8	80.5	82.0	80.6	81.4	82.3	82.4	82.3	82.5	83.2	82.6	82.8	84.6	84.0	84.4
16	80.1	80.6	81.8	80.8	81.3	82.1	82.3	82.1	82.4	83.0	82.4	82.7	84.6	83.9	84.3
17	80.2	80.7	81.6	81.0	81.3	81.9	82.2	81.9	82.2	82.9	82.3	82.6	84.6	83.8	84.2
18	80.9	81.1	81.8	81.5	81.4	82.1	82.4	81.9	82.4	83.0	82.3	82.7	84.6	83.7	84.2
19	81.4	81.4	82.0	81.9	81.6	82.3	82.6	81.9	82.5	83.1	82.3	82.9	84.6	83.6	84.3
20	81.8	81.7	82.2	82.3	81.7	82.4	82.8	82.0	82.7	83.2	82.3	83.0	84.6	83.5	84.3
21	82.2	82.0	82.4	82.6	81.8	82.7	82.9	82.0	82.9	83.3	82.2	83.2	84.6	83.4	84.4
22	82.6	82.3	82.7	83.0	81.9	82.9	83.1	82.0	83.2	83.4	82.2	83.4	84.6	83.3	84.6
23	83.0	82.6	83.0	83.2	82.0	83.2	83.2	82.0	83.5	83.5	82.2	83.7	84.7	83.3	84.9
24	82.8	82.6	83.0	83.3	82.0	83.3	83.2	81.9	83.6	83.5	82.2	84.0	84.7	83.2	85.2
25	82.9	82.7	83.3	83.5	82.1	83.6	83.3	82.0	83.9	83.5	82.2	84.3	84.7	83.2	85.6
26	83.2	82.9	83.7	83.7	82.2	84.0	83.5	82.1	84.3	83.7	82.4	84.7	84.8	83.3	86.0
27	83.5	83.1	84.0	83.9	82.4	84.4	83.7	82.3	84.7	83.8	82.5	85.1	84.9	83.5	86.4
28	83.7	83.4	84.5	84.2	82.7	84.8	83.9	82.5	85.1	84.0	82.8	85.5	85.1	83.8	87.0
29	84.0	83.7	84.9	84.4	83.0	85.3	84.1	82.9	85.6	84.2	83.1	86.0	85.3	84.1	87.5
30	84.3	84.0	85.3	84.6	83.4	85.7	84.4	83.3	86.1	84.5	83.5	86.5	85.6	84.6	88.1
31	84.5	84.3	85.6	84.9	83.8	86.0	84.7	83.7	86.4	84.9	84.0	86.9	86.0	85.1	88.6
32	84.6	84.5	85.7	85.1	84.2	86.2	85.1	84.3	86.6	85.3	84.6	87.1	86.5	85.8	89.0
33	84.7	84.8	86.0	85.4	84.7	86.5	85.5	84.9	86.9	85.8	85.2	87.4	87.1	86.6	89.4
34	85.0	85.2	86.2	85.8	85.3	86.8	86.1	85.6	87.2	86.4	86.0	87.8	87.9	87.5	89.8
35	85.3	85.5	86.5	86.2	85.8	87.1	86.7	86.2	87.5	87.2	86.5	88.1	88.8	88.4	90.2
36	85.5	85.8	86.8	86.6	86.1	87.3	87.5	86.5	87.8	88.1	87.0	88.4	90.1	88.8	90.7
37	85.8	86.0	87.0	87.0	86.4	87.5	88.4	86.9	88.0	89.2	87.4	88.6	91.8	89.3	90.9
38	86.0	86.2	87.2	87.3	86.7	87.7	88.8	87.2	88.2	89.7	87.7	88.8	92.6	89.8	91.1
39	86.3	86.5	87.4	87.4	87.0	87.9	88.8	87.6	88.4	89.7	88.1	89.0	92.5	90.3	91.4
40	86.5	86.7	87.5	87.5	87.3	88.0	88.8	87.9	88.5	89.6	88.5	89.1	92.4	90.8	91.4
41	86.7	86.9	87.6	87.6	87.4	88.1	88.8	88.1	88.6	89.6	88.6	89.1	92.3	91.0	91.5
42	87.0	87.0	87.7	87.8	87.4	88.2	88.8	88.0	88.7	89.6	88.6	89.2	92.2	90.9	91.5
43	86.7	86.9	87.6	87.9	87.4	88.2	88.9	87.9	88.7	89.5	88.4	89.3	92.1	90.7	91.6
44	86.9	87.0	87.7	88.0	87.4	88.3	88.9	87.9	88.8	89.5	88.4	89.4	92.0	90.6	91.7
45	87.0	87.1	87.8	88.1	87.4	88.4	88.9	87.9	88.9	89.5	88.3	89.5	92.0	90.5	91.8
46	87.2	87.2	87.9	88.2	87.4	88.5	88.9	87.9	89.0	89.5	88.3	89.5	91.9	90.3	91.8
47	87.4	87.3	88.0	88.2	87.4	88.5	89.0	87.8	89.0	89.5	88.2	89.6	91.8	90.2	91.8
48	87.6	87.4	88.1	88.3	87.4	88.6	89.0	87.8	89.1	89.6	88.2	89.6	91.8	90.1	91.8
49	87.7	87.5	88.2	88.4	87.5	88.7	89.0	87.8	89.2	89.6	88.2	89.7	91.7	90.1	91.9
50	87.9	87.6	88.3	88.5	87.5	88.8	89.1	87.8	89.3	89.6	88.2	89.8	91.6	90.0	92.0
51	88.1	87.7	88.4	88.6	87.5	88.9	89.1	87.8	89.4	89.6	88.2	89.9	91.6	90.0	92.1
52	87.9	87.6	88.4	88.6	87.5	88.9	89.2	87.8	89.4	89.6	88.2	90.0	91.5	90.0	92.2
53	88.0	87.7	88.5	88.7	87.5	89.1	89.2	87.9	89.6	89.5	88.2	90.1	91.5	89.9	92.3
54	88.2	87.8	88.6	88.8	87.6	89.2	89.2	87.9	89.7	89.5	88.2	90.2	91.5	89.9	92.4
55	88.3	87.9	88.7	88.8	87.6	89.3	89.3	87.9	89.8	89.7	88.3	90.4	91.5	90.0	92.5
56	88.5	88.0	88.9	88.9	87.7	89.4	89.4	88.0	89.9	89.7	88.3	90.5	91.5	90.0	92.7
57	88.5	88.1	89.0	88.9	87.8	89.5	89.4	88.1	90.1	89.8	88.4	90.6	91.5	90.1	92.8
58	88.7	88.2	89.1	89.0	87.8	89.7	89.5	88.1	90.2	89.9	88.5	90.7	91.6	90.2	93.0

REPRODUCED AT GOVERNMENT EXPENSE

TABLE A-2
(Continued)

59	88 9	88 3	89 2	89 1	87 9	89 8	89 3	88 2	90 3	90 0	88 6	90 9	91 6	90 3	93 1
60	88 8	88 3	89 3	89 1	88 0	89 9	89 6	88 3	90 4	90 0	88 7	91 0	91 7	90 4	93 3
61	89 0	88 3	89 4	89 2	88 1	90 0	89 7	88 3	90 6	90 2	88 9	91 2	91 8	90 6	93 3
62	89 1	88 6	89 3	89 2	88 2	90 2	89 8	88 6	90 7	90 3	89 0	91 3	91 9	90 7	93 6
63	89 2	88 7	89 7	89 3	88 4	90 3	89 9	88 8	90 8	90 4	89 2	91 3	92 1	90 9	93 8
64	89 3	88 8	89 8	89 4	88 3	90 4	90 0	88 9	91 0	90 6	89 4	91 6	92 3	91 1	94 0
65	89 3	89 0	90 0	89 4	88 6	90 6	90 1	89 1	91 1	90 7	89 6	91 8	92 3	91 3	94 2
66	89 6	89 1	90 1	89 3	88 8	90 7	90 2	89 2	91 3	90 9	89 8	91 9	92 7	91 6	94 4
67	89 7	89 3	90 2	89 6	88 9	90 9	90 3	89 4	91 4	91 1	90 0	92 1	92 9	91 8	94 6
68	89 9	89 4	90 4	89 7	89 1	91 0	90 4	89 6	91 6	91 3	90 2	92 2	93 2	92 1	94 8
69	89 9	89 3	90 4	89 8	89 2	91 1	90 6	89 8	91 7	91 3	90 4	92 3	93 3	92 4	94 9
70	90 0	89 6	90 3	89 9	89 4	91 2	90 7	89 9	91 8	91 8	90 6	92 4	93 8	92 7	95 1
71	90 1	89 8	90 6	90 0	89 3	91 3	90 8	90 1	91 9	92 0	90 9	92 6	94 2	93 0	95 2
72	90 3	89 9	90 7	90 1	89 7	91 4	91 0	90 3	92 0	92 3	91 1	92 7	94 6	93 3	95 4
73	90 4	90 0	90 9	90 2	89 8	91 3	91 1	90 4	92 1	92 3	91 2	92 8	95 0	93 3	95 3
74	90 3	90 1	91 0	90 3	89 8	91 6	91 2	90 3	92 3	92 8	91 3	92 9	95 3	93 6	95 7
75	90 7	90 2	91 0	90 4	89 9	91 7	91 4	90 3	92 4	93 0	91 4	93 0	96 0	93 7	95 8
76	90 8	90 3	91 1	90 4	90 0	91 8	91 3	90 6	92 3	93 0	91 3	93 1	96 0	93 9	95 9
77	90 8	90 4	91 2	90 3	90 0	91 9	91 3	90 6	92 3	92 9	91 3	93 2	95 9	94 0	96 0
78	90 9	90 3	91 2	90 3	90 1	92 0	91 2	90 7	92 6	92 8	91 6	93 3	95 9	94 1	96 1
79	91 0	90 3	91 3	90 3	90 1	92 0	91 2	90 7	92 7	92 7	91 6	93 4	95 8	94 1	96 1
80	91 1	90 6	91 4	90 6	90 1	92 1	91 1	90 6	92 7	92 7	91 6	93 4	95 7	94 1	96 2
81	91 2	90 6	91 3	90 6	90 1	92 2	91 1	90 6	92 8	92 6	91 3	93 3	95 7	94 0	96 3
82	91 4	90 7	91 3	90 6	90 2	92 3	91 0	90 6	92 9	92 3	91 3	93 6	95 6	94 0	96 4
83	91 3	90 3	91 6	90 7	90 2	92 3	91 0	90 6	93 0	92 4	91 3	93 6	95 6	94 0	96 4
84	91 6	90 8	91 7	90 7	90 2	92 4	91 0	90 6	93 0	92 4	91 3	93 7	95 6	94 0	96 3
85	91 7	90 9	91 7	90 8	90 2	92 3	91 0	90 6	93 1	92 3	91 4	93 8	95 6	94 0	96 6
86	91 8	91 0	91 8	90 9	90 2	92 3	91 0	90 6	93 1	92 3	91 4	93 8	95 3	94 0	96 6
87	91 9	91 0	91 8	90 9	90 3	92 6	91 0	90 6	93 2	92 2	91 4	93 9	95 3	94 0	96 7
88	92 0	91 1	91 9	91 0	90 3	92 6	91 0	90 6	93 3	92 2	91 3	94 0	95 3	94 0	96 7
89	92 1	91 2	92 0	91 0	90 4	92 7	91 0	90 6	93 3	92 2	91 3	94 0	95 6	94 1	96 8
90	92 2	91 3	92 0	91 1	90 4	92 8	91 0	90 6	93 4	92 2	91 3	94 1	95 6	94 1	96 9
91	92 3	91 3	92 1	91 2	90 3	92 8	91 0	90 7	93 3	92 1	91 3	94 2	95 6	94 2	97 0
92	92 4	91 4	92 2	91 3	90 3	92 9	91 1	90 7	93 3	92 1	91 6	94 2	95 6	94 2	97 0
93	92 6	91 3	92 3	91 3	90 6	93 0	91 1	90 8	93 6	92 1	91 6	94 3	95 7	94 3	97 1
94	92 7	91 6	92 3	91 4	90 7	93 1	91 1	90 8	93 7	92 2	91 6	94 4	95 8	94 4	97 2
95	92 7	91 7	92 4	91 3	90 8	93 1	91 2	90 9	93 8	92 2	91 7	94 3	95 8	94 4	97 3
96	92 8	91 8	92 3	91 6	90 8	93 2	91 2	91 0	93 8	92 2	91 8	94 6	95 9	94 3	97 4
97	92 9	91 9	92 3	91 7	90 9	93 3	91 3	91 0	93 9	92 2	91 8	94 6	96 0	94 6	97 3
98	93 1	92 0	92 6	91 8	91 0	93 4	91 4	91 1	94 0	92 2	91 9	94 7	96 0	94 7	97 6
99	93 2	92 1	92 7	91 9	91 1	93 3	91 4	91 2	94 1	92 3	92 0	94 8	96 2	94 9	97 7
100	93 3	92 2	92 8	92 0	91 2	93 3	91 3	91 3	94 2	92 3	92 0	94 9	96 3	95 0	97 9
101	93 4	92 3	92 9	92 1	91 3	93 6	91 6	91 4	94 3	92 4	92 1	95 0	96 4	95 1	98 0
102	93 3	92 4	92 9	92 2	91 4	93 7	91 7	91 3	94 4	92 3	92 2	95 1	96 3	95 3	98 1
103	93 6	92 3	93 0	92 3	91 3	93 8	91 8	91 6	94 3	92 3	92 3	95 2	96 7	95 4	98 2
104	93 7	92 6	93 1	92 4	91 6	93 9	91 9	91 7	94 6	92 6	92 4	95 3	96 8	95 3	98 3
105	93 8	92 7	93 2	92 3	91 8	94 0	92 0	91 8	94 7	92 7	92 3	95 4	97 0	95 7	98 3
106	93 9	92 8	93 3	92 6	91 9	94 0	92 1	91 9	94 7	92 8	92 6	95 3	97 2	95 8	98 6
107	94 0	92 9	93 3	92 8	92 0	94 1	92 2	92 0	94 8	92 9	92 7	95 6	97 3	96 0	98 7
108	94 1	93 0	93 4	92 9	92 1	94 2	92 3	92 1	94 9	93 0	92 8	95 7	97 3	96 1	98 8
109	94 2	93 1	93 3	93 0	92 2	94 3	92 3	92 2	95 0	93 1	92 9	95 7	97 7	96 3	98 9
110	94 3	93 2	93 3	93 1	92 4	94 3	92 6	92 4	95 0	93 2	93 0	95 8	98 0	96 3	99 0
111	94 3	93 3	93 6	93 3	92 3	94 4	92 7	92 4	95 1	93 4	93 1	95 9	98 2	96 3	99 1
112	94 3	93 4	93 7	93 4	92 3	94 3	92 9	92 3	95 2	93 3	93 2	96 0	98 4	96 6	99 2
113	94 6	93 3	93 7	93 3	92 6	94 3	93 0	92 6	95 3	93 6	93 2	96 0	98 7	96 7	99 3
114	94 7	93 6	93 8	93 6	92 7	94 6	93 1	92 7	95 3	93 7	93 3	96 1	98 6	96 8	99 4
115	94 8	93 7	93 8	93 7	92 8	94 7	93 1	92 8	95 4	93 7	93 4	96 2	98 5	96 8	99 4
116	94 9	93 8	93 9	93 8	92 9	94 7	93 2	92 9	95 4	93 7	93 4	96 2	98 5	96 9	99 4
117	95 0	93 9	93 9	93 8	93 0	94 8	93 3	92 9	95 3	93 8	93 3	96 3	98 5	96 9	99 3
118	95 1	93 9	94 0	93 9	93 1	94 8	93 3	93 0	95 3	93 8	93 3	96 3	98 5	96 9	99 3
119	95 2	94 0	94 1	94 0	93 1	94 8	93 4	93 0	95 4	93 8	93 3	96 3	98 5	96 9	99 7
120	95 3	94 1	94 1	94 1	93 2	94 9	93 3	93 1	95 6	93 9	93 6	96 4	98 5	96 9	99 7

REPRODUCED AT GOVERNMENT EXPENSE

TABLE A-2
(Continued)

	315 Hz			630 Hz			900 Hz			1250 Hz			1600 Hz		
Mile	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep
1	68.0	62.7	64.8	68.0	62.7	64.9	68.1	62.8	65.0	68.3	62.9	65.0	68.4	62.9	65.1
2	71.8	69.1	71.9	71.9	69.2	72.2	72.2	69.4	72.3	72.5	69.6	72.4	72.8	69.8	72.4
3	74.4	74.4	74.5	74.5	74.5	74.9	74.9	74.9	75.1	75.4	75.4	75.2	75.7	75.7	75.3
4	76.5	76.5	76.8	76.7	76.7	77.5	77.2	77.1	77.7	77.7	77.7	77.8	78.1	78.1	77.9
5	78.2	78.2	79.2	78.5	78.5	80.1	79.1	79.1	80.4	79.7	79.7	80.5	80.1	80.1	80.4
6	79.8	79.8	81.6	80.2	80.2	83.0	80.9	80.9	83.4	81.5	81.5	83.3	81.8	81.8	83.0
7	81.2	81.2	84.3	81.7	81.7	86.6	82.5	82.5	87.1	83.1	83.1	86.5	83.3	83.3	85.7
8	82.5	82.5	85.5	83.1	83.1	88.1	84.0	84.0	88.7	84.5	84.5	87.9	84.5	84.5	86.7
9	83.5	83.5	85.9	84.4	84.4	89.0	85.4	85.4	89.6	85.8	85.8	88.6	85.6	85.6	87.2
10	84.1	84.0	85.8	85.6	85.6	89.6	86.7	86.6	90.3	86.9	86.8	89.1	86.4	86.3	87.6
11	84.5	84.3	85.7	86.7	86.6	90.2	87.8	87.7	90.9	87.9	87.8	89.5	87.1	87.0	87.9
12	84.8	84.6	85.6	87.7	87.5	90.5	88.9	88.7	91.4	88.7	88.5	89.9	87.7	87.5	88.2
13	85.0	84.7	85.4	88.2	87.9	90.2	89.8	89.6	91.9	89.5	89.2	90.3	88.2	87.9	88.4
14	85.2	84.7	85.3	88.5	88.0	89.7	90.7	90.4	92.4	90.1	89.7	90.7	88.7	88.2	88.7
15	85.2	84.6	85.2	88.6	88.0	89.2	91.5	91.1	92.5	90.7	90.2	91.0	89.1	88.5	89.0
16	85.3	84.6	85.1	88.6	87.9	88.8	91.9	91.0	92.1	91.2	90.5	91.1	89.4	88.8	89.2
17	85.3	84.5	85.0	88.6	87.6	88.4	91.8	90.7	91.5	91.4	90.5	91.0	89.7	89.0	89.5
18	85.3	84.3	84.9	88.4	87.3	88.1	91.6	90.3	91.0	91.4	90.3	90.9	90.1	89.7	89.8
19	85.3	84.2	84.9	88.3	87.0	87.8	91.3	89.8	90.5	91.4	90.2	90.8	90.4	89.5	90.2
20	85.2	84.1	84.9	88.2	86.7	87.6	91.0	89.4	90.2	91.4	90.0	90.8	90.7	89.7	90.5
21	85.2	83.9	85.0	88.0	86.5	87.6	90.8	89.0	90.0	91.4	89.9	90.9	91.0	89.9	90.9
22	85.2	83.8	85.2	87.9	86.2	87.6	90.6	88.6	89.9	91.4	89.7	91.1	91.3	90.1	91.4
23	85.2	83.7	85.4	87.8	86.0	87.8	90.4	88.3	90.0	91.4	89.7	91.4	91.6	90.3	91.9
24	85.2	83.7	85.7	87.7	85.9	88.0	90.1	88.1	90.2	91.5	89.7	91.8	91.9	90.5	92.5
25	85.3	83.7	86.1	87.6	85.8	88.3	89.9	88.0	90.5	91.5	89.8	92.2	92.2	90.8	93.1
26	85.3	83.8	86.5	87.5	85.8	88.8	89.8	88.0	90.9	91.6	89.9	92.8	92.6	91.2	93.8
27	85.4	83.9	87.0	87.5	86.0	89.3	89.7	88.1	91.5	91.7	90.2	93.5	93.0	91.6	94.5
28	85.5	84.2	87.5	87.6	86.2	89.9	89.7	88.3	92.1	92.0	90.6	94.2	93.4	92.1	95.3
29	85.8	84.5	88.1	87.8	86.6	90.7	89.9	88.7	92.9	92.3	91.1	95.0	93.9	92.6	96.1
30	86.1	85.0	88.8	88.1	87.1	91.5	90.1	89.2	93.8	92.7	91.7	96.0	94.4	93.3	96.9
31	86.4	85.6	89.3	88.5	87.7	92.2	90.5	89.9	94.6	93.2	92.5	96.8	95.1	94.1	97.7
32	86.9	86.3	89.7	89.0	88.6	92.8	91.1	90.8	95.3	93.9	93.4	97.6	95.8	95.0	98.4
33	87.6	87.1	90.2	89.7	89.6	93.4	91.8	91.9	96.0	94.8	94.5	98.4	96.7	96.1	99.1
34	88.4	88.1	90.7	90.8	90.8	94.1	92.9	93.3	96.9	95.9	95.9	99.3	97.7	97.3	99.8
35	89.5	89.1	91.2	92.1	92.1	94.9	94.4	94.7	97.9	97.4	97.3	100.2	99.0	98.5	100.6
36	91.0	89.6	91.6	94.2	92.8	95.8	96.8	95.6	99.1	99.6	98.2	101.2	100.7	99.3	101.4
37	93.0	90.1	91.9	97.9	93.7	96.3	101.5	96.7	99.9	103.5	99.2	101.9	102.9	100.1	102.0
38	94.0	90.7	92.2	100.6	94.7	96.8	106.8	98.0	100.7	106.5	100.4	102.6	104.2	101.0	102.6
39	93.8	91.3	92.4	100.3	95.8	97.3	106.3	99.6	101.5	106.4	101.7	103.3	104.4	102.0	103.2
40	93.7	91.9	92.5	99.9	97.1	97.4	105.8	101.8	101.7	106.2	103.4	103.6	104.6	103.0	103.6
41	93.6	92.1	92.5	99.6	97.6	97.5	105.3	102.9	102.0	106.1	104.2	103.9	104.8	103.7	104.0
42	93.4	91.9	92.6	99.3	97.3	97.5	104.9	102.4	102.1	105.9	104.0	104.2	105.0	103.8	104.4
43	93.3	91.8	92.7	99.0	96.9	97.6	104.5	101.9	102.3	105.8	103.9	104.5	105.2	104.0	104.8
44	93.2	91.6	92.7	98.8	96.6	97.7	104.2	101.5	102.4	105.7	103.7	104.7	105.4	104.1	105.2
45	93.1	91.4	92.8	98.5	96.3	97.6	103.8	101.1	102.4	105.6	103.5	104.9	105.6	104.3	105.6
46	93.0	91.3	92.8	98.3	96.0	97.5	103.5	100.7	102.2	105.6	103.4	105.0	105.8	104.4	105.9
47	92.9	91.2	92.8	98.1	95.7	97.4	103.2	100.3	102.0	105.5	103.3	105.0	106.0	104.6	106.2
48	92.8	91.0	92.8	97.8	95.5	97.4	102.8	100.1	101.9	105.4	103.3	105.1	106.2	104.8	106.5
49	92.7	91.0	92.8	97.6	95.3	97.4	102.4	99.8	101.9	105.3	103.2	105.3	106.4	105.0	106.8
50	92.6	90.9	92.9	97.3	95.2	97.4	102.1	99.6	101.8	105.3	103.2	105.4	106.6	105.2	107.2
51	92.5	90.8	93.0	97.1	95.1	97.5	101.8	99.5	101.9	105.2	103.3	105.6	106.9	105.4	107.5
52	92.4	90.8	93.1	96.9	95.0	97.5	101.5	99.4	101.9	105.2	103.3	105.8	107.1	105.6	107.9
53	92.4	90.9	93.2	96.8	94.9	97.7	101.2	99.3	102.0	105.2	103.4	106.1	107.4	105.9	108.3
54	92.4	90.8	93.3	96.6	94.9	97.8	101.0	99.2	102.2	105.2	103.5	106.2	107.5	106.1	108.7
55	92.3	90.8	93.5	96.5	94.9	97.9	100.9	99.2	102.3	105.2	103.6	106.4	107.8	106.4	109.0

REPRODUCED AT GOVERNMENT EXPENSE

TABLE A-2
(Continued)

56	92.3	90.8	93.6	96.5	94.9	98.1	100.7	99.2	102.5	105.3	103.7	106.9	108.2	106.7	109.5
57	92.4	90.9	93.8	96.4	95.0	98.3	100.6	99.3	102.7	105.4	103.9	107.2	108.5	107.0	109.9
58	92.4	91.0	93.9	96.4	95.1	98.5	100.6	99.4	103.0	105.5	104.1	107.6	108.8	107.4	110.3
59	92.4	91.1	94.1	96.4	95.2	98.7	100.6	99.5	103.2	105.6	104.4	107.9	109.1	107.7	110.7
60	92.5	91.2	94.3	96.5	95.3	99.0	100.6	99.7	103.5	105.8	104.7	108.3	109.5	108.1	111.2
61	92.6	91.4	94.5	96.5	95.5	99.2	100.7	99.9	103.8	106.0	105.0	108.7	109.8	108.5	111.6
62	92.7	91.5	94.7	96.7	95.8	99.5	100.8	100.2	104.2	106.3	105.3	109.1	110.2	108.9	112.1
63	92.9	91.7	94.9	96.8	96.0	99.8	101.0	100.5	104.5	106.6	105.7	109.5	110.6	109.4	112.5
64	93.1	92.0	95.1	97.0	96.3	100.1	101.2	100.8	104.9	106.9	106.1	110.0	111.0	109.7	113.0
65	93.3	92.2	95.3	97.3	96.6	100.4	101.5	101.2	105.4	107.3	106.6	110.5	111.5	110.4	113.5
66	93.5	92.5	95.5	97.6	97.0	100.7	101.8	101.6	105.8	107.7	107.1	111.0	112.0	110.9	114.0
67	93.8	92.7	95.7	97.9	97.4	101.1	102.2	102.1	106.3	108.2	107.6	111.5	112.5	111.4	114.5
68	94.1	93.0	95.9	98.4	97.8	101.4	102.7	102.6	106.8	108.8	108.2	112.0	113.0	112.0	115.1
69	94.4	93.3	96.1	98.9	98.2	101.7	103.3	103.2	107.1	109.4	108.8	112.4	113.6	112.6	115.5
70	94.8	93.7	96.2	99.4	98.7	101.9	104.0	103.9	107.5	110.1	109.5	112.8	114.3	113.2	116.0
71	95.3	94.0	96.4	100.1	99.2	102.2	104.8	104.6	107.9	110.9	110.2	113.3	115.0	113.9	116.4
72	95.7	94.4	96.6	100.9	99.8	102.5	105.8	105.4	108.3	111.9	111.0	113.7	115.7	114.6	116.9
73	96.2	94.6	96.7	101.8	100.2	102.8	107.0	106.0	108.7	113.0	111.6	114.2	116.5	115.2	117.4
74	96.7	94.7	96.9	102.8	100.5	103.0	108.7	106.4	109.1	114.3	112.0	114.7	117.4	115.7	117.9
75	97.4	94.9	97.0	104.2	100.8	103.2	111.0	106.8	109.4	116.0	112.5	115.0	118.5	116.1	118.4
76	97.4	95.0	97.2	104.3	101.0	103.4	111.3	107.2	109.7	116.3	113.0	115.4	118.8	116.6	118.8
77	97.3	95.2	97.3	104.0	101.3	103.5	111.0	107.6	109.9	116.2	113.4	115.7	119.0	117.1	119.2
78	97.2	95.3	97.3	103.8	101.5	103.7	110.6	108.0	110.0	116.2	113.9	116.0	119.2	117.6	119.6
79	97.1	95.3	97.4	103.6	101.5	103.8	110.3	108.1	110.2	116.1	114.1	116.3	119.5	117.9	119.9
80	97.0	95.2	97.5	103.4	101.4	103.9	110.1	108.0	110.3	116.1	114.1	116.5	119.7	118.1	120.3
81	96.9	95.2	97.6	103.2	101.4	104.0	109.8	107.9	110.5	116.0	114.2	116.8	119.9	118.4	120.7
82	96.9	95.2	97.7	103.1	101.3	104.1	109.6	107.8	110.7	116.0	114.3	117.1	120.1	118.6	121.1
83	96.8	95.1	97.7	102.9	101.2	104.2	109.4	107.7	110.7	116.0	114.3	117.3	120.3	118.8	121.4
84	96.8	95.1	97.8	102.8	101.2	104.2	109.2	107.7	110.8	116.0	114.4	117.5	120.6	119.1	121.7
85	96.7	95.1	97.8	102.7	101.2	104.3	109.1	107.7	110.9	116.1	114.5	117.7	120.8	119.3	122.1
86	96.7	95.1	97.9	102.6	101.2	104.4	108.9	107.6	111.0	116.1	114.7	117.9	121.1	119.6	122.4
87	96.7	95.1	98.0	102.5	101.2	104.4	108.8	107.7	111.1	116.2	114.8	118.1	121.3	119.8	122.7
88	96.7	95.2	98.0	102.5	101.2	104.5	108.7	107.7	111.2	116.3	115.0	118.3	121.6	120.1	123.1
89	96.7	95.2	98.1	102.4	101.2	104.6	108.6	107.7	111.3	116.3	115.1	118.6	121.9	120.4	123.4
90	96.7	95.2	98.2	102.4	101.3	104.7	108.6	107.8	111.4	116.5	115.3	118.8	122.2	120.7	123.7
91	96.7	95.3	98.3	102.4	101.4	104.8	108.6	107.9	111.6	116.6	115.5	119.0	122.4	121.0	124.1
92	96.7	95.3	98.4	102.4	101.4	105.0	108.6	108.0	111.8	116.7	115.7	119.3	122.7	121.3	124.4
93	96.8	95.4	98.4	102.5	101.5	105.1	108.6	108.2	111.9	116.9	115.9	119.6	123.0	121.7	124.8
94	96.8	95.5	98.5	102.5	101.6	105.2	108.7	108.3	112.1	117.1	116.2	119.9	123.4	122.0	125.2
95	96.9	95.6	98.6	102.6	101.8	105.4	108.7	108.5	112.3	117.3	116.4	120.1	123.7	122.4	125.5
96	97.0	95.7	98.7	102.7	101.9	105.5	108.8	108.7	112.5	117.5	116.7	120.4	124.0	122.7	125.9
97	97.1	95.8	98.9	102.8	102.1	105.7	109.0	108.9	112.8	117.7	117.0	120.8	124.4	123.1	126.3
98	97.2	95.9	99.0	102.9	102.2	105.9	109.1	109.1	113.0	118.0	117.3	121.1	124.7	123.5	126.7
99	97.3	96.1	99.1	103.0	102.4	106.1	109.3	109.3	113.3	118.3	117.7	121.4	125.1	123.9	127.1
100	97.4	96.2	99.2	103.2	102.6	106.3	109.5	109.6	113.6	118.6	118.0	121.8	125.5	124.3	127.5
101	97.5	96.3	99.4	103.4	102.9	106.5	109.8	109.9	113.9	118.9	118.4	122.1	125.9	124.7	127.9
102	97.7	96.5	99.5	103.6	103.1	106.7	110.1	110.2	114.2	119.3	118.7	122.5	126.3	125.1	128.3
103	97.8	96.6	99.7	103.9	103.3	106.9	110.4	110.5	114.5	119.7	119.1	122.9	126.7	125.5	128.8
104	98.0	96.8	99.8	104.1	103.6	107.2	110.7	110.9	114.8	120.1	119.5	123.3	127.1	126.0	129.2
105	98.2	97.0	100.0	104.4	103.8	107.4	111.1	111.3	115.2	120.5	120.0	123.7	127.6	126.4	129.7
106	98.4	97.1	100.1	104.8	104.1	107.6	111.6	111.6	115.5	121.0	120.3	124.1	128.1	126.9	130.1
107	98.6	97.3	100.2	105.1	104.4	107.8	112.1	112.1	115.8	121.5	120.9	124.4	128.6	127.4	130.5
108	98.8	97.5	100.3	105.5	104.7	108.0	112.6	112.5	116.1	122.1	121.4	124.8	129.1	127.9	130.9
109	99.1	97.7	100.4	105.9	105.0	108.2	113.2	112.9	116.3	122.7	121.9	125.2	129.7	128.4	131.3
110	99.3	97.8	100.5	106.4	105.4	108.4	113.9	113.4	116.7	123.4	122.4	125.6	130.3	129.0	131.8
111	99.6	97.9	100.7	106.9	105.5	108.6	114.7	113.7	117.0	124.1	122.9	126.0	130.9	129.4	132.2
112	99.9	98.0	100.8	107.4	105.7	108.8	115.5	113.9	117.2	124.9	123.1	126.3	131.6	129.8	132.6
113	100.2	98.1	100.9	108.0	105.8	108.9	116.5	114.2	117.4	125.8	123.4	126.6	132.3	130.2	133.0
114	100.1	98.2	100.9	107.9	106.0	109.1	116.3	114.4	117.6	125.8	123.8	126.9	132.5	130.6	133.4
115	100.1	98.3	101.0	107.8	106.1	109.2	116.2	114.7	117.8	125.8	124.1	127.2	132.7	131.0	133.7
116	100.0	98.4	101.1	107.7	106.3	109.3	116.0	114.8	117.9	125.9	124.6	127.4	133.2	131.4	134.4
117	100.0	98.4	101.1	107.6	106.3	109.4	115.9	114.9	118.1	125.9	124.6	127.7	133.2	131.7	134.4
118	100.0	98.3	101.2	107.5	106.3	109.5	115.8	114.9	118.2	126.0	124.7	127.9	133.4	131.9	134.8
119	99.9	98.3	101.3	107.4	106.3	109.6	115.7	114.9	118.4	126.0	124.8	128.2	133.7	132.2	135.2
120	99.9	98.4	101.3	107.4	106.3	109.7	115.6	115.0	118.5	126.1	125.0	128.4	133.9	132.4	135.5

REPRODUCED AT GOVERNMENT EXPENSE

TABLE A-2
(Continued)

	2000 Hz			2500 Hz			3500 Hz			5000 Hz			10000 Hz		
Mile	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep	In	Cross	Deep
1	68.6	63.0	65.1	68.8	63.1	65.2	69.2	63.3	65.3	69.9	63.7	65.6	72.2	65.3	67.0
2	73.1	70.0	72.6	73.5	70.3	72.7	74.3	70.7	73.0	75.4	71.5	73.5	79.9	75.0	76.5
3	76.2	76.2	75.5	76.8	76.8	75.7	77.9	77.9	76.1	79.5	79.5	76.9	85.7	85.7	81.3
4	78.7	78.7	78.1	79.4	79.4	78.4	80.8	80.8	78.9	82.7	82.7	80.0	90.3	90.3	85.8
5	80.8	80.8	80.7	81.6	81.6	81.0	83.1	83.1	81.7	85.3	85.3	83.1	93.9	93.9	90.3
6	82.5	82.5	83.3	83.4	83.4	83.7	85.0	85.0	84.6	87.3	87.3	86.2	96.9	96.9	94.8
7	84.0	84.0	86.1	84.9	84.9	86.5	86.5	86.5	87.5	88.9	88.9	89.4	99.6	99.6	99.4
8	85.3	85.3	87.1	86.2	86.2	87.7	87.8	87.8	88.8	90.3	90.3	90.8	102.1	102.1	102.3
9	86.4	86.4	87.7	87.3	87.2	88.2	88.9	88.8	89.5	91.5	91.4	91.8	104.6	104.5	104.6
10	87.2	87.1	88.1	88.1	88.0	88.7	89.7	89.6	90.0	92.4	92.3	92.6	106.9	106.7	106.8
11	87.9	87.7	88.4	88.7	88.5	89.1	90.4	90.2	90.5	93.3	93.1	93.3	109.1	108.9	109.0
12	88.5	88.2	88.7	89.3	89.0	89.4	91.0	90.7	91.0	94.2	93.9	94.0	111.3	111.0	111.2
13	89.0	88.6	89.0	89.8	89.5	89.8	91.6	91.2	91.5	95.0	94.6	94.8	113.5	113.2	113.3
14	89.4	89.0	89.3	90.3	89.8	90.1	92.2	91.7	91.9	95.8	95.5	95.5	115.7	115.3	115.5
15	89.8	89.3	89.6	90.7	90.2	90.5	92.7	92.2	92.4	96.6	96.0	96.2	117.9	117.4	117.6
16	90.2	89.6	89.9	91.1	90.5	90.9	93.2	92.6	92.9	97.3	96.7	97.0	120.1	119.5	119.8
17	90.6	89.8	90.3	91.5	90.8	91.2	93.8	93.0	93.4	98.1	97.4	97.8	122.3	121.6	122.0
18	90.9	90.1	90.6	91.9	91.1	91.6	94.3	93.5	94.0	98.9	98.0	98.5	124.5	123.7	124.2
19	91.2	90.3	91.0	92.3	91.4	92.1	94.8	93.9	94.5	99.6	98.7	99.4	126.7	125.8	126.4
20	91.6	90.6	91.4	92.7	91.7	92.5	95.3	94.3	95.1	100.4	99.4	100.2	128.9	127.9	128.7
21	91.9	90.8	91.9	93.1	92.0	93.1	95.8	94.7	95.8	101.2	100.0	101.1	131.1	130.0	131.0
22	92.3	91.1	92.4	93.5	92.3	93.6	96.3	95.1	96.5	101.9	100.7	102.1	133.3	132.1	133.4
23	92.6	91.3	92.9	93.9	92.6	94.2	96.9	95.6	97.2	102.7	101.4	103.0	135.5	134.2	135.8
24	93.0	91.6	93.6	94.3	93.0	94.9	97.4	96.1	98.0	103.5	102.1	104.1	137.7	136.4	138.3
25	93.3	91.9	94.2	94.7	93.3	95.6	98.0	96.6	98.9	104.3	102.9	105.2	140.0	138.6	140.8
26	93.7	92.3	94.9	95.2	93.8	96.4	98.6	97.1	99.8	105.2	103.7	106.4	142.2	140.8	143.4
27	94.2	92.8	95.7	95.7	94.3	97.2	99.2	97.8	100.7	106.0	104.6	107.6	144.5	143.1	146.0
28	94.6	93.3	96.5	96.2	94.9	98.1	99.8	98.5	101.7	106.9	105.6	108.8	146.9	145.5	148.7
29	95.2	93.9	97.4	96.8	95.6	99.0	100.6	99.3	102.7	107.9	106.7	110.1	149.3	148.0	151.4
30	95.8	94.7	98.3	97.5	96.4	100.0	101.3	100.2	103.8	108.9	107.8	111.4	151.7	150.6	154.2
31	96.5	95.5	99.1	98.2	97.2	100.8	102.2	101.2	104.8	110.1	109.1	112.7	154.3	153.3	156.9
32	97.2	96.5	99.8	99.0	98.3	101.6	103.2	102.4	105.7	111.3	110.5	113.8	156.9	156.1	159.5
33	98.2	97.6	100.5	100.0	99.4	102.4	104.3	103.7	106.7	112.6	112.1	115.0	159.7	159.1	162.1
34	99.2	98.8	101.3	101.2	100.7	103.2	105.5	105.1	107.6	114.2	113.8	116.2	162.6	162.2	164.7
35	100.6	100.1	102.1	102.5	102.0	104.1	107.1	106.5	108.6	115.9	115.4	117.5	165.8	165.3	167.4
36	102.3	100.9	103.0	104.3	102.9	105.0	108.9	107.6	109.6	118.1	116.7	118.8	169.4	168.0	170.1
37	104.5	101.8	103.6	106.6	103.8	105.7	111.4	108.6	110.5	120.8	118.0	119.9	173.5	170.8	172.6
38	105.9	102.7	104.3	108.0	104.8	106.4	112.9	109.7	111.3	122.6	119.4	120.9	176.8	173.6	175.1
39	106.1	103.7	104.9	108.3	105.9	107.1	113.3	110.9	112.1	123.2	120.8	122.0	178.8	176.4	177.6
40	106.3	104.8	105.3	108.6	107.1	107.6	113.8	112.2	112.7	123.9	122.4	122.9	180.9	179.4	179.9
41	106.6	105.5	105.8	108.9	107.8	108.1	114.2	113.1	113.4	124.6	123.5	123.8	183.0	182.0	182.2
42	106.8	105.7	106.2	109.2	108.0	108.6	114.6	113.5	114.0	125.3	124.1	124.7	185.1	184.0	184.6
43	107.1	105.9	106.7	109.5	108.3	109.1	115.0	113.8	114.7	125.9	124.8	125.6	187.2	186.1	186.9
44	107.3	106.1	107.2	109.8	108.5	109.6	115.5	114.2	115.3	126.6	125.4	126.5	189.4	188.1	189.2
45	107.6	106.3	107.6	110.1	108.8	110.1	115.9	114.6	115.9	127.3	126.0	127.4	191.5	190.2	191.5
46	107.8	106.5	107.9	110.4	109.1	110.5	116.3	115.0	116.4	128.0	126.7	128.1	193.6	192.3	193.7
47	108.1	106.7	108.3	110.7	109.3	110.9	116.8	115.4	117.0	128.7	127.3	128.9	195.7	194.3	195.9
48	108.3	106.9	108.6	111.0	109.6	111.3	117.2	115.8	117.5	129.4	128.0	129.7	197.8	196.4	198.1
49	108.6	107.2	109.0	111.3	109.9	111.8	117.7	116.2	118.1	130.1	128.7	130.5	200.0	198.5	200.4
50	108.9	107.4	109.4	111.7	110.2	112.2	118.1	116.7	118.7	130.8	129.4	131.4	202.1	200.7	202.6
51	109.1	107.7	109.8	112.0	110.5	112.7	118.6	117.1	119.2	131.5	130.1	132.2	204.2	202.8	204.9
52	109.4	107.9	110.2	112.3	110.9	113.1	119.0	117.6	119.6	132.2	130.8	133.0	206.4	204.9	207.2

REPRODUCED AT GOVERNMENT EXPENSE

TABLE A-2
(Continued)

53	109	7	108	3	110	6	112	7	111	2	113	6	119	5	118	1	120	4	133	0	131	5	133	9	208	5	207	1	209	5
54	110	0	108	5	111	0	113	0	111	6	114	1	120	0	118	5	121	0	133	7	132	3	134	8	210	7	209	2	211	7
55	110	3	108	9	111	3	113	4	111	9	114	6	120	3	119	0	121	7	134	5	133	0	135	6	212	9	211	4	214	0
56	110	7	109	2	111	9	113	8	112	3	115	1	121	0	119	6	122	3	135	2	133	8	136	5	215	1	213	6	216	4
57	111	0	109	6	112	4	114	2	112	8	115	6	121	6	120	1	122	9	136	0	134	6	137	4	217	3	215	8	218	7
58	111	3	109	9	112	9	114	6	113	2	116	1	122	1	120	7	123	6	136	8	135	4	138	3	219	5	218	1	220	0
59	111	7	110	3	113	3	115	0	113	6	116	6	122	6	121	3	124	3	137	6	136	2	139	2	220	0	220	0	220	0
60	112	1	110	8	113	8	115	3	114	1	117	2	123	2	121	9	124	9	138	5	137	1	140	2	220	0	220	0	220	0
61	112	5	111	2	114	3	115	9	114	6	117	7	123	8	122	5	125	6	139	3	138	0	141	1	220	0	220	0	220	0
62	112	9	111	7	114	8	116	4	115	2	118	3	124	4	123	2	126	3	140	2	138	9	142	0	220	0	220	0	220	0
63	113	4	112	2	115	3	116	9	115	7	118	9	125	1	123	8	127	0	141	1	139	8	143	0	220	0	220	0	220	0
64	113	9	112	7	115	9	117	5	116	3	119	5	125	7	124	6	127	7	142	0	140	8	144	0	220	0	220	0	220	0
65	114	4	113	2	116	4	118	0	116	9	120	0	126	4	125	3	128	4	142	9	141	8	144	9	220	0	220	0	220	0
66	114	9	113	8	116	9	118	6	117	5	120	6	127	1	126	0	129	2	143	9	142	8	145	9	220	0	220	0	220	0
67	115	3	114	4	117	5	119	2	118	2	121	3	127	9	126	8	129	9	144	9	143	8	146	9	220	0	220	0	220	0
68	116	0	115	0	118	1	119	9	118	8	121	9	128	6	127	6	130	7	145	9	144	9	147	9	220	0	220	0	220	0
69	116	7	115	7	118	6	120	6	119	5	122	4	129	5	128	5	131	3	147	0	146	0	148	9	220	0	220	0	220	0
70	117	4	116	3	119	1	121	3	120	3	123	0	130	3	129	3	132	0	148	1	147	1	149	8	220	0	220	0	220	0
71	118	1	117	1	119	6	122	1	121	0	123	6	131	3	130	2	132	7	149	3	148	2	150	8	220	0	220	0	220	0
72	118	9	117	8	120	1	122	9	121	9	124	2	132	2	131	1	133	5	150	5	149	4	151	7	220	0	220	0	220	0
73	119	8	118	4	120	7	123	9	122	5	124	8	133	3	132	0	134	2	151	8	150	5	152	7	220	0	220	0	220	0
74	120	7	118	9	121	2	124	9	123	1	125	3	134	4	132	7	134	9	153	2	151	4	153	7	220	0	220	0	220	0
75	121	8	119	5	121	7	126	0	123	7	125	9	135	7	133	4	135	6	154	7	152	4	154	6	220	0	220	0	220	0
76	122	2	120	0	122	2	126	5	124	3	126	4	136	3	134	1	136	2	155	6	153	4	155	5	220	0	220	0	220	0
77	122	4	120	5	122	6	126	8	124	9	126	9	136	7	134	8	136	9	156	3	154	3	156	4	220	0	220	0	220	0
78	122	7	121	1	123	0	127	1	125	5	127	4	137	1	135	5	137	5	156	9	155	3	157	3	220	0	220	0	220	0
79	122	9	121	4	123	4	127	4	125	9	127	9	137	6	136	1	138	1	157	6	156	1	158	1	220	0	220	0	220	0
80	123	2	121	7	123	8	127	7	126	2	128	3	138	0	136	5	138	7	158	3	156	8	159	0	220	0	220	0	220	0
81	123	5	121	9	124	3	128	0	126	5	128	8	138	5	136	9	139	3	159	0	157	5	159	9	220	0	220	0	220	0
82	123	7	122	2	124	7	128	4	126	8	129	3	138	9	137	4	139	9	159	8	158	2	160	7	220	0	220	0	220	0
83	124	0	122	5	125	1	128	7	127	2	129	8	139	4	137	9	140	5	160	5	158	9	161	5	220	0	220	0	220	0
84	124	3	122	8	125	5	129	0	127	5	130	2	139	9	138	3	141	0	161	2	159	7	162	3	220	0	220	0	220	0
85	124	6	123	1	125	8	129	4	127	9	130	6	140	3	138	8	141	6	161	9	160	4	163	1	220	0	220	0	220	0
86	124	9	123	4	126	2	129	7	128	2	131	0	140	8	139	3	142	1	162	7	161	2	164	0	220	0	220	0	220	0
87	125	2	123	7	126	6	130	1	128	6	131	5	141	3	139	8	142	7	163	4	161	9	164	8	220	0	220	0	220	0
88	125	5	124	0	126	9	130	4	129	0	131	9	141	8	140	3	143	2	164	1	162	7	165	6	220	0	220	0	220	0
89	125	8	124	4	127	3	130	8	129	4	132	3	142	3	140	8	143	8	164	9	163	4	166	4	220	0	220	0	220	0
90	126	1	124	7	127	7	131	2	129	8	132	8	142	8	141	4	144	4	165	7	164	2	167	2	220	0	220	0	220	0
91	126	5	125	1	128	1	131	6	130	2	133	2	143	3	141	9	145	0	166	4	165	0	168	1	220	0	220	0	220	0
92	126	8	125	4	128	5	132	0	130	6	133	7	143	9	142	5	145	6	167	2	165	8	168	9	220	0	220	0	220	0
93	127	2	125	8	128	9	132	4	131	0	134	1	144	4	143	0	146	1	168	0	166	6	169	8	220	0	220	0	220	0
94	127	5	126	2	129	3	132	8	131	5	134	6	144	9	143	6	146	7	168	8	167	5	170	6	220	0	220	0	220	0
95	127	9	126	6	129	7	133	2	131	9	135	1	145	5	144	2	147	3	169	6	168	3	171	5	220	0	220	0	220	0
96	128	3	127	0	130	2	133	7	132	4	135	6	146	0	144	8	148	0	170	4	169	1	172	3	220	0	220	0	220	0
97	128	7	127	4	130	6	134	1	132	8	136	1	146	6	145	4	148	6	171	3	170	0	173	2	220	0	220	0	220	0
98	129	1	127	8	131	0	134	6	133	3	136	5	147	2	146	0	149	2	172	1	170	9	174	1	220	0	220	0	220	0
99	129	5	128	3	131	5	135	0	133	8	137	0	147	8	146	6	149	8	172	9	171	7	175	0	220	0	220	0	220	0
100	129	9	128	7	131	9	135	5	134	3	137	6	148	4	147	2	150	5	173	8	172	6	175	9	220	0	220	0	220	0
101	130	3	129	2	132	4	136	0	134	8	138	1	149	0	147	9	151	1	174	7	173	3	176	7	220	0	220	0	220	0
102	130	8	129	6	132	9	136	5	135	4	138	6	149	7	148	5	151	8	175	6	174	4	177	7	220	0	220	0	220	0
103	131	3	130	1	133	3	137	1	135	9	139	1	150	3	149	2	152	4	176	5	175	3	178	6	220	0	220	0	220	0
104	131	7	130	6	133	8	137	6	136	4	139	7	151	0	149	9	153	1	177	4	176	3	179	5	220	0	220	0	220	0
105	132	3	131	1	134	3	138	2	137	0	140	2	151	7	150	5	153	8	178	4	177	2	180	4	220	0	220	0	220	0
106	132	8	131	6	134	8	138	7	137	6	140	7	152	4	151	2	154	4	179	3	178	2	181	3	220	0	220	0	220	0
107	133	3	132	1	135	2	139	4	138	1	141	2	153	2	152	0	155	0	180	3	179	1	182	2	220	0	220	0	220	0
108	133	9	132	7	135	7	140	0	138	7	141	8</																		

BIBLIOGRAPHY

Beran, Ernest K., A Command and Control Assessment Methodology with Applications Using the Warfare Environmental Simulator (WES), Master's Thesis, Naval Postgraduate School, Monterey, California, June 1981.

B-K Dynamics, Inc., Battle Group Training Computer Support Facility (BGTCFS) Passive Sonar T&E Plan and Results, September 1983.

Chief of Naval Operations, Letter Ser. 953D11/350433 to Commander, Naval Ocean Systems Center, Subject: Policy and Procedure for the Operation and Utilization of the Interim Battle Group Tactical Trainer Computer Support Facility (IBGTT/CSF), 26 November 1982.

Chief of Naval Operations, Message DTG R 211858Z Jan 83 to CINCPACFLT Pearl Harbor, HI, CINCLANTFLT Norfolk, VA, CINCUSNAVEUR London, UK, Subject: Interim Battle Group Tactical Trainer (IBGTT) Capabilities, January 1983.

Kinsler, Lawrence E., and others, Fundamentals of Acoustics, Third Edition, John Wiley and Sons, 1982.

Miller, Irwin and Fruend, John E., Probability and Statistics for Engineers, Second Edition, Prentice Hall, Inc., 1977.

Naval Ocean Systems Center, Interim Battle Group Tactical Trainer (IBGTT) Introductory Student User's Guide, San Diego, California, 30 November 1983.

Naval Operations Analysis, Second Edition, U.S. Naval Institute, 1977.

Pacer Systems, Inc., Interim Battle Group Tactical Trainer IBGTT Instructor User's Guide, Volume I through V, prepared for Naval Ocean Systems Center, San Diego, California, 17 January 1983.

Pacer Systems, Inc., Interim Battle Group Tactical Trainer IBGTT Student User's Guide, prepared for Naval Ocean Systems Center, San Diego, California, 30 January 1983.

Urlick, Robert J., Principles of Underwater Sound, Second Edition, McGraw-Hill, 1975.

Watson, Jr., Paul B. and Abernathy, Thomas, R., Wargaming with a Digital Computer--A Discussion and an Example, Master's Thesis, Naval Postgraduate School, Monterey, California, 1961.

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